State Form 4336

DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
INDIANAPOLIS

OFFICE MEMORANDUM

Date: January 20, 2011

To: Mark Jaworski
State Investigations Section

Thru: Larry Studebaker, [illegible] 1/21/11
Geological Services Section

From: Bob Martin, Geologist RM 1-20-11
Geology Section for Geological Services

Subject: Hydrogeologic Assessment
Gary Development Landfill
Gary, Lake County
Site #051133611 (L58QW)

SITE REVIEW

Per your request, a hydrogeologic assessment for the Gary Development Landfill has been completed. The assessment was performed for the purpose of scoring the landfill on the National Priorities List. The assessment is based on the review of existing documentation contained in the reference list of this memo.

GENERAL COMMENTS

The Gary Development Landfill is an abandoned landfill encompassing an area of approximately 55 acres. Based on aerial photographs archived with the Indiana Geological Survey (information available online at: http://129.79.145.7/arcims/IHAPI/viewer.htm) the landfill appears to have originated as a soil borrow pit during the early 1950s. Aerial photography shows that by 1970, the borrow pit had expanded to include nearly the entire site and had completely filled with water. Later, water was pumped from the pit and the pit was again used as a source of aggregate for additional roadway construction, notably the Indiana Toll Road. Subsequently, the borrow pit was used for waste disposal until 1986. During operation, the facility illegally accepted and disposed hazardous waste. The Environmental Protection Agency (EPA) sued the owners and established a $40,000 trust fund for closure. As part of the EPA action, the site was covered and four ground water monitoring wells were installed. According to the EPA, fly ash was used for the final cover material. Currently, the landfill cover material appears to support some vegetation, but is eroding, as evidenced by the formation of leachate outbreaks around the perimeter of the landfill. A surface water pond, measured to be approximately 3.5 acres, is present inside the northern boundary of the fill area. The size of the pond is variable, as it expands and contracts with precipitation and surface water runoff.

SPECIFIC COMMENTS

The Gary Development Landfill occupies the area between the Grand Calumet River and Gary road to the north, Cline Avenue to the west and the Gary/Chicago International Airport to the east. Specifically, the landfill is located in the northern half of the southwest quarter of Section 35, Township 37 North, Range 9 West, Lake County, Indiana (Figure 1).

This location lies within the Lake Michigan Border physiographic division of the Northern Moraine and Lake Region of Indiana. The Lake Michigan Border includes a four to 11 mile swath of land south of the Lake Michigan shoreline. The geomorphology of the Lake Michigan Border area is characterized by the presence of beach ridges, dunes, moraines, numerous lakes and peat bogs (Gray, 2000). Landforms occur as elongated ridges with alternating sloughs and interridge marshes oriented parallel to the Lake Michigan shoreline and orthogonal to prevailing wind directions. Relief varies from 650 ft above sea level at the tops of dune and beach ridges, to as low as 580 ft at the shoreline (Fenelon and others, 1994).

The landscape surrounding the Gary Development Landfill and in northern Lake County in general, has been significantly altered by industrial and urban development. Predominant soil types in the area (Figure 2) include the Oakville-Adrian soil complex (map symbol OkB), Houghton muck (map symbol Ca) and Urban land (map symbol Ur). The Oakville-Adrian complex is characterized by eolian (windblown) ridges underlain by sandy sediments and intervening sloughs of muck. Oakville soils are developed in well drained silty-sand deposits that occupy the tops of dune ridges and interfluve (areas without drainage) uplands between adjacent drainageways. Adrian soils occur in depressions of outwash plains (areas of relatively course sediments deposited by melt water in front of glaciers), dunes (accumulations of sand by wind or water) and terrace surfaces containing muck (dark accumulation of decomposed organic matter and fine sediments that are very poorly drained). Similar to Houghton muck, Adrian muck collects in low lying areas, but Houghton muck accumulates to greater thicknesses on poorly drained surfaces of glaciolacustrine (glacial lakes) plains, and moraines (areas underlain by glacial sediments). Depressions containing Adrian and Houghton mucks often contain water, forming marshes and wetlands (information available online at: http://websoilsurvey.nrcs.usda.gov/). Urban land is present primarily on Oakville-Adrian soils that have been filled with earth, cinders, slag, trash, or combinations of these materials; and leveled to grade (USDA, 1972). Urban land is used primarily for industry and community development.

As part of an evaluation of the ground water resources, Rosenshein (1962) used the expression of surface deposits and subsurface geologic information to develop a tentative glacial stratigraphy (horizontal and vertical arrangement) and chronology of the unconsolidated deposits in Lake County (Figure 3). His findings indicated the presence of four main distinct lithologic units ranging in age from Holocene (younger than 10,000 years) to early Pleistocene (1.8 million years). Unit 1, the shallow-most and youngest lithology of the deposits, was dated as Holocene to late Wisconsinan (older than 10,000 years) age consisting predominantly of fine to medium grained sand with beach gravel, silt and clay interbeds (layered between) containing organics. Sediment thickness was found to range from zero to as much as 70 feet. Interpreted as glaciolacustrine and eolian in origin, these deposits are the parent materials upon which modern surface soils described above have formed. Deeper and older, Rosenshein notes lithologic Units 2 and 3 consist of clay till (sediments laid down directly or indirectly by the action of glacial ice) with interbeds of sand and gravel, and glaciofluvial (glacial sediments carried by rivers) sand, respectively. Neither Unit 2 or 3, however, are shown to occur in close proximity to the Lake Michigan shoreline, nor beneath the Gary Development Landfill. Beneath deposits of Unit 1, but above the underlying bedrock, Unit 4 is described as an early Wisconsinan, or possibly pre-Wisconsinan glacial till. Unit 4 is characterized as locally hard and compact pebbly, sandy, silty, clay till reaching thicknesses of up to 150 ft. In northern Lake County, Unit 4 contains thin beds of sand and gravel near the base with thicker accumulations occurring in preglacial valleys. Unit 4 mantles the upper surfaces of Silurian, Devonian and Mississippian age dolomite and dolomitic limestone bedrock.

Since the work of Rosenshein, additional studies have been completed in Lake County altering earlier interpretations of the geology. One such study is the work of Brown and Thompson (2005). This study is significant in that it compiles and summarizes the work of many earlier investigations, providing a broad overview of the surficial geology during the past 15, 000 years. Utilizing water well records, geologic and engineering soil boring log descriptions and samples, grain-size analyses, down-hole geophysical logging, and vibracore samples, this study interprets and maps landforms and their depositional successions in terms of geologic terrains or sequences consisting of related sediment types deposited in related depositional environments over the past 15, 000 years.

Multiple water level fluctuations of Lake Michigan over the past 13,500 years resulted in the deposition of late Wisconsinan (older than 10, 000 years) to Holocene (less than 10, 000 year old) age sediments (Figure 3). Named the Lake Michigan Sequence, this succession of sediments records the deposition of sediments in proglacial (in front of the glacier) lakes, and post-glacial lakes. In the area of the Gary Development Landfill, water level changes occurring over the past 5,500 years created a repetitive succession of parallel progradational (building outward towards water) dunes, beach ridges, spits and swales (outward projections of the beach). Collectively, these landforms are referred to as the Toleston beach strandplain (map symbol Qts). Still active, beach ridges measure 35 to 50 ft thick and consist of onshore (above water) deposits overlying nearshore (beneath the water at the shoreline) deposits. Onshore deposits are identified by the occurrence of fine to medium unstratified (massive) dune sand overlying stratified (layered) medium grained sand to sandy gravel foreshore (the outer seaward sloping surface of the shore lying between the upper limit of wave wash occurring at high tide and the low water mark) deposits. Nearshore deposits consist of both the upper and lower-shoreface (a zone parallel to the beach sloping lakeward permanently covered by water) deposits. The upper-shoreface is marked by the occurrence of cross-bedded (inclined layers one or more cm. in thickness) and rippled (small ridges or waves) fine to medium grained sand, and the lower-shoreface by very fine grained sand to fine grained sand and silty sand with mud flasers (accumulations of mud in troughs of cross beds) and stringers (thin beds of mud). Alteration of these deposits continues to the present.

Underlying the Toleston strandplain, nearshore and fluvial deposits were laid down during earlier Holocene transgressions (rises in lake levels) of ancestral Lake Michigan. Deposits of the Toleston transgression (map symbol Qtt) vary significantly in lithology ranging from mud to sandy gravel beds with locally thick accumulations of soft sandy, silty to loamy, commonly fossiliferous and/or organic rich sediments generally less than 20 ft thick. Toleston nearshore and fluvial deposits accumulated between 6,000 to 8,300 years ago during the Two-Creeks and Chippewa Phases of glaciation, and also during the increase in lake level during the transition to the Nipissing Phase. Deposits of the Lake Michigan Sequence correlate to those of Unit 1 described by Rosenshein.

Earlier, during a short-lived advance of late Wisconsinan ice and till deposition (map symbol Qbt), continuous deposition of stratified sand, silt and clay (map symbol Qbl) occurred in a shallow ice-margin lake throughout the Glenwood Phases of ancestral Lake Michigan (11,000 to 11,800 years ago). Defined as the Lake Border Sequence, these sediments are vertically interstratified (present between) and intergrade (transition) laterally with deposits of the till. Lake sediments near the bottom indicate deposition in a proglacial, ice-margin lake while those near the top represent deposition into deeper water of ancestral Lake Michigan. Upper lake sediments are laterally continuous and mark the top of the Lake Border Sequence. The advance of ice over lake sediments formed a distinctive soft clay loam, silty clay loam, and silty clay till sequence that coarsens upward. Beneath the area of the Gary Development Landfill, upper lake deposits approximately 5 ft thick overlie deposits of till nearly 30 ft thick. The Lake Border Sequence locally includes proglacial, subaqueous debris flows (sediment flows beneath the water surface) and fine grained lacustrine sediments at the base.

Flanked by deposits of the Lake Border Sequence above and the bedrock below, another late Wisconsinan glacial till occurs. This till represents late Wisconsinan deposits of the older Wheeler Sequence (map symbol Qwt). In contrast to the overlying till above, the texture of this till is predominantly silty clay loam with more silt and sand. The till is also harder and contains many more Devonian-age Antrim Shale clasts. The till also is interstratified with sediments of thin, fine grained debris flows that are variable in texture. Near the top and base, thicker debris flows are present which in turn are interstratified with thin laminations of lacustrine silt and clay. These deposits are equivalent to Unit 4 and possibly lower sections of the till of Unit 2 where lake sediments of Unit 3 are absent. The thickness of this unit beneath the Gary Development Landfill is mapped to be approximately 55 ft.

Underlying the base of the unconsolidated till and debris flow deposits of the Wheeler Sequence, Silurian age (417 – 443 million years old) bedrock (consolidated rock beneath the ground surface) of the Wabash Formation is present (Brown and Thompson, 2005). The Wabash formation consists of various carbonate lithologies (sedimentary rocks), but principally of three types including: dolomitic siltstones, limestone and dolomitic limestone, and massive, nearly pure dolomite containing vugs or cavities. Near Lake Michigan the formation may be as much as 250 ft thick along the northern limit (Shaver and others, 1970).

Soil boring logs obtained from the Indiana Department of Highways (INDOH, 1989) completed immediately adjacent to the Gary Development Landfill prior to the construction of the Indiana Toll Road, provide limited site-specific information (Appendix 1). Boring logs completed for engineering purposes, demonstrate sand is present beneath an approximate two ft veneer of fill. Sand extends from the surface at an elevation of about 590 ft above mean sea level (msl), to an average depth of approximately 40 feet at 550 ft above msl. Boring logs describe sandy deposits as brown, loose to dense, fine sand; overlying gray, dense fine sand. The occurrence of a 1.5 ft layer of wood at the bottom of a layer of sand in Boring # 1022B (which occurs at approximately 555.0 ft above msl), suggests that deposits of the Toleston transgression (Qtt) are present at this elevation. Boring # 1039E, describes a soft to medium stiff, silty clay with traces of fine sand, shells and gravel at 550 ft above msl. The occurrence of the soft silty clay at this elevation probably marks the upper surface of the notably soft, Lake Border till (Qbt). Boring # 1039E also describes an abrupt transition from gray, medium stiff silty clay, to gray, hard silty clay at an elevation of 500 ft above msl. The abrupt transition from medium stiff to hard, suggests the contact between the Lake Border till (Qbt) and till of the Wheeler Sequence (Qwt) beneath, occurs at an elevation of about 499 ft above msl. The contact between till of the Wheeler Sequence and bedrock is variable. Although Boring # 1010A encounted bedrock at an elevation of 505.9 ft above msl, Borings # 1022B and 1039E did not, even though these borings were completed to elevations of 491 and 479 ft, respectfully. The bedrock encountered in Boring # 1010A is described as hard, gray, finely crystalline, slightly weathered dolomitic limestone with close to very closely spaced, vugs (filled joints) and oil/tar filled cavities.

Hydrologically, the Gary Development Landfill is located in the Lake Michigan Basin water management area of Indiana that includes the northern halves of Lake and Porter Counties and northern one-third of LaPorte County. The Lake Michigan basin includes 845 sq miles of which 604 sq miles are land. South of the Toleston beach surface water drains by way of a network of tributaries that collectively flow northward into the Little Calumet River. In turn, the Little Calumet River flows parallel to the lakeshore, emptying into Lake Michigan via a ditch located in Porter County, east of Ogden Dunes (Fenelon and others, 1994). North of the Toleston beach, however, surface water discharges to the Grand Calumet River, the Indiana Harbor canal and like Michigan (Cohen and others, 2002).

The Grand Calumet River flanks the Gary Development Landfill immediately to the south. As much as 90 percent of the discharge in the river originates as industrial and municipal waste water effluent (Cohen and others, 2002). For water years 1995 thru 2008, the mean annual discharge was 496 cubic feet per second as recorded by Gaging Station 04092677 (Grand Calumet River at Indusrial Highway at Gary, Indiana) located 1.5 miles east of the Gary Development Landfill (Appendix 2). Surface water records for this gaging station, dating back to October 1985 (personal communication with Donald Arvin, USGS); demonstrate that discharge and velocity have remained above zero. Thus, surface water in the Grand Calumet River has continuously flowed east to west towards its discharge point into the Indiana Harbor Canal.

Hydrostratigraphically, the area surrounding the Gary Development Landfill is underlain by the eolian and glaciolacustrine deposits of Units 1 and clay till of Unit 4 described by Rosenshein (1962), or the differentiated deposits of the Lake Michigan, Lake Border, and Wheeler Sequences described by Brown and Thompson (2005). The uppermost eolian and glaciolustrine deposits form the surficial, water table Calumet aquifer which extends as much as 10 miles inland from the shore of Lake Michigan. As illustrated by soil borings installed immediately adjacent to the site (INDOH, 1989), the shallow sand aquifer extends to a depth of approximately 40 ft where it contacts the upper surface of the lower till. Water levels, obtained from USGS well C-5 screened in this aquifer, show water levels have fluctuated as much as 4.4 ft, or from 584.56 to 581.98 ft above msl since 1985 (Appendix 2). The aquifer is recharged principally by the infiltration of precipitation from above and by the upward flow of ground water through the till beneath. Horizontal hydraulic conductivities for this unit are significant and are reported to average 17.9 ft/day (Cohen and others, 2002). Due to the close proximity of Lake Michigan and extreme susceptibility to contamination, this aquifer is not used as a source of drinking water (Fenelon and Others, 1994).

A comparison of stream gage heights recorded at USGS Gaging Station 04092677, located on the Grand Calumet River 1.5 miles upstream of the Gary Development Landfill, with static water levels recorded in USGS wells C-5, C-10, and C-12 (Appendix 2) located 3000 ft west of the landfill, demonstrates that surface and ground water flow directions are variable. As Table 1 shows, when stream gage heights are elevated, surface water infiltrates the surficial aquifer as recharge. In response to gradient reversals which occur during periods of low stage, however, ground water baseflow discharges to the river. Baseflow accounts for only about 10% of the total stream flow.

Due to the low vertical hydraulic conductivity of the underlying till, estimated to be 0.003 gpd/sq ft, significant ground water flow through this hydrostratigraphic unit does not occur. The till, therefore, serves as a confining unit to both the upper sand and lower bedrock aquifers (Cohen and others, 2002). Nevertheless, percolation of ground water through the till to the bedrock aquifer does occur and in 1968, recharge from the confining till unit was estimated to average 20,000 gpd per square mile. Locally, in areas where the till is interstratified with glaciolacustrine sand and gravel, 100,000 gpd of ground water may be discharged (Rosenshein and Hunn, 1968). Soil boring logs (INDOH, 1989) demonstrate the till beneath the Gary Development Landfill varies in thickness from 50 to 70 ft, but lack interstratified sand and gravel layers.

As described previously, the depth to the top of the confined bedrock aquifer ranges from 85 to 110 ft beneath the Gary Development Landfill. The Wabash formation consists of various carbonate lithologies up to 250 ft thick, but wells in the area seldom penetrate the bedrock more than 100 ft. Although ground water yield rates of the bedrock were determined to be generally less than 200 gpm, pumping discharge from the bedrock aquifer in 1968, was estimated at 1.4 mgd (Rosenshein and Hunn, 1968). Depending on the actual ground water usage today, it is possible that shallow ground water contamination through the till confining unit could be induced downward into the lower lying bedrock.

Information obtained from an inspection of the Gary Development Landfill (Kearney, 1984) conducted by Harding Lawson Associates on September 19, 1984, concludes existing site-specific hydrogeologic data are insufficient and monitoring wells were not adequately constructed for the purpose of conducting RCRA ground water monitoring (Kearney, 1984). Since this time, no additional site-specific ground water monitoring or hydrogeologic information has been obtained.

CONCLUSION

The Gary Development Landfill is an abandoned landfill encompassing nearly 55 acres. The landfill began as an aggregate borrow pit and was later used as a landfill in which hazardous wastes were disposed. Although a trust fund was established by the EPA, funds were not sufficient to properly close the site.

The landfill lies within the Lake Michigan Border physiographic division of the Northern Lake and Moraine Region of Indiana. This region is characterized by the presence of beach ridges, dunes, moraines, numerous lakes and peat bogs. The landscape surrounding the site has been significantly altered by industrial and urban development. Predominant soil types include the Oakville-Adrian soil complex, Houghton muck and Urban land.

Rosenshein (1962) used the expression of surface deposits and subsurface geologic information to develop a tentative glacial stratigraphy and chronology of the unconsolidated deposits in Lake County. In the area of the landfill, Rosenshein identified the presence of two distinct unconsolidated lithologies. The uppermost unit was determined to be Holocene, or late Wisconsinan eolian and glaciolacustrine sand and gravel, the lower an early Wisconsinan, or pre-Wisconsinan clay till.

Brown and Thompson (2005) later compiled and summarized earlier work and continued the investigation of the surficial geology of the northern third of Lake County. They concluded that multiple water level fluctuations of Lake Michigan over the past 13,500 years, culminated in the formation of three distinct successions of deposits named the Lake Michigan, Lake Border and Wheeler Sequences. Beneath the unconsolidated deposits of the Wheeler Sequence, carbonate bedrock of the Wabash Formation was encountered.

Beneath the Gary Development Landfill, soil boring logs demonstrate sand and gravel deposit extends from the surface to an average depth of approximately 40 feet at 550 ft above msl. Deeper boring logs describe the occurrence of soft silty clay transitioning to gray, hard silty clay till. At this location, the till is approximately 50 ft thick, extending downward to an elevation of 505 to 479 ft above msl, where it contacts the upper bedrock surface. The bedrock is described as hard, gray and finely crystalline dolomitic limestone containing closely spaced solution joints and tar-filled cavities.

Hydrologically, the Gary Development Landfill is located in the Lake Michigan Basin water management area of Indiana. The uppermost eolian and glaciolastrine deposits form the surficial, water table Calumet aquifer. Discharge to the Grand Calumet River originates primarily as industrial waste water and city effluent having a mean annual discharge of 496 cubic feet per second. Although surface water in the Grand Calumet River continuously flows east to west, the hydraulic gradient of the river relative to the ground water table determines whether surface water recharges the aquifer, or baseflow from the aquifer discharges as surface water.

The uppermost eolian and glaciolustrine deposits form the surficial, water table Calumet aquifer which extends as much as 10 miles inland from the shore of Lake Michigan. Soil borings adjacent to the site show the shallow sand aquifer extends to a depth of 40 ft where it comes into contact with the upper surface of the lower till. Since 1985, water levels have fluctuated between 584.56 to 581.98 ft above msl, or 4.4 ft. Recharge to the aquifer occurs principally by the infiltration of precipitation from above and to a lesser extent by the upward flow of ground water through the till beneath. Due to the lack of an impermeable cap above land filled wastes and the substantial hydraulic conductivities of the Calumet aquifer, surface recharge from above and ground water flow through the aquifer are likely to transport contaminants from the landfill to adjacent wetlands and Grand Calumet River. The till serves as a confining unit to both the upper sand and lower bedrock aquifers. Boring logs demonstrate the till beneath the landfill ranges in thickness from 50 to 70 ft. Together, the sand aquifer and confining till have a combined thickness of 90 to 110 ft above bedrock. Beneath the unconsolidated deposits, bedrock of the Wabash formation consists of various carbonate lithologies up to 250 ft thick. Although ground water yield rates of the bedrock aquifer were determined to be less than 200 gpm, it is not known whether surface contamination could be induced downward through the till confining unit and surficial sand aquifer above.

An ERTEC Inspection conducted in 1984 concluded that existing site-specific hydrogeologic data were insufficient and monitoring wells were not adequately constructed for the purpose of conducting RCRA ground water monitoring (Kearney, 1984). Since this time, no additional site-specific information has been obtained.

Further site specific investigation is warranted to determine the impact of the Gary Development Landfill on the quality of ground water contained in the aquifers below.

REFERENCES

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REM/
Attachments:

- Figures 1 – 3
- Table 1
- Appendix 1 (Boring Logs)
- Appendix 2 (USGS National Water Information System: Web Interface Stream Flow and Ground-water levels for the Nation)
- Appendix 3 (References)

FIGURES

REFERENCE 92
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Google maps Address **Gary, IN 46406**

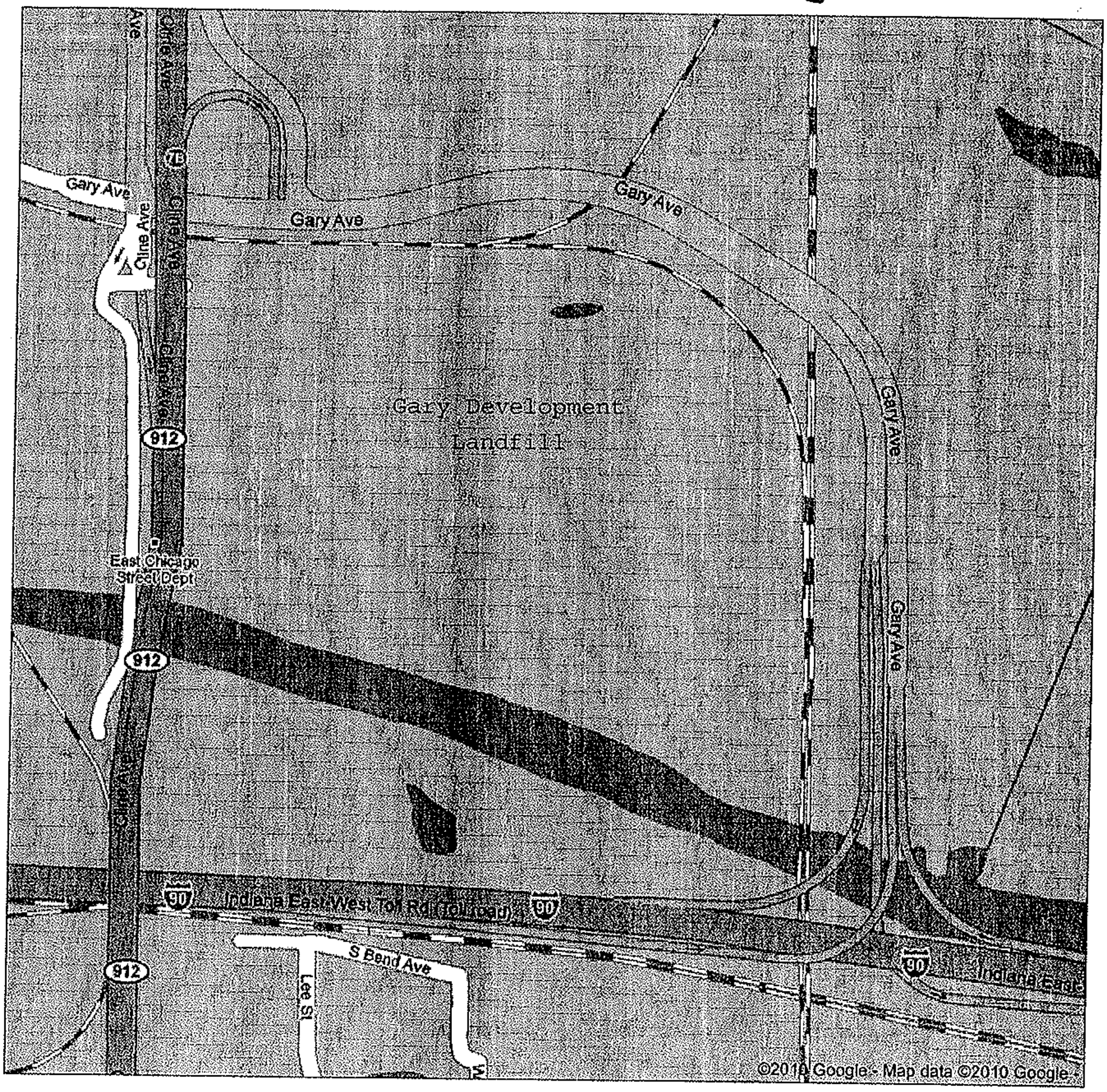


Figure 1

Soil Map—Lake County, Indiana
(Figure 2 - Gary Development Landfill Soil Types)

Map Scale: 1:14,600 if printed on A size (8.5" x 11") sheet.

N

Meters: 0 100 200 400 600

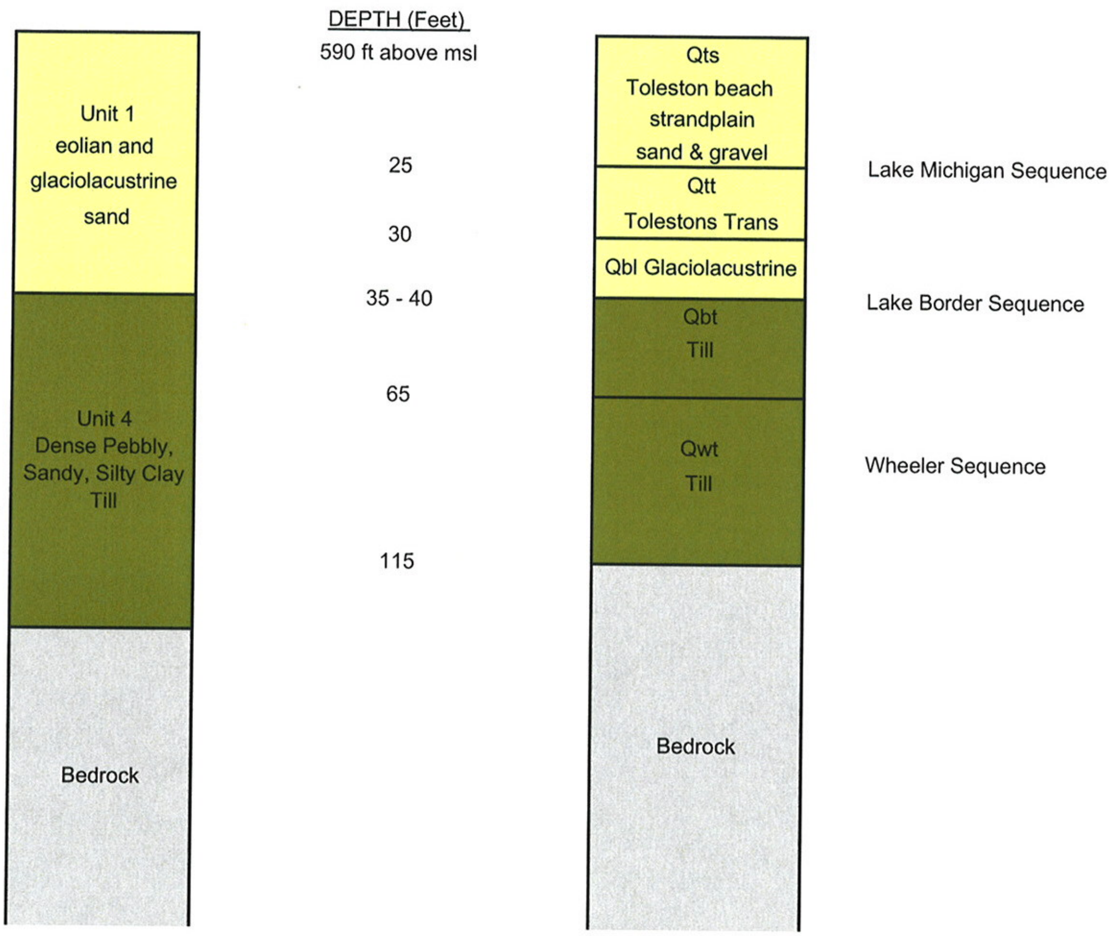
Feet: 0 500 1,000 2,000 3,000

Map Unit Legend

Lake County, Indiana (IN089)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
Ca	Houghton muck, drained, 0 to 1 percent slopes	7.1	0.8%
Mh	Marsh	17.9	2.0%
OkB	Oakville-Adrian complex, 0 to 6 percent slopes	319.4	36.3%
Ta	Adrian muck, drained, 0 to 1 percent slopes	19.5	2.2%
Ur	Urban land	479.4	54.5%
W	Water	36.1	4.1%
Totals for Area of Interest		**879.5**	**100.0%**

FIGURE 3

STRATIGRAPHY OF UNCONSOILDATED DEPOSITS
Beneath the Gary Development Landfill - Lake County, IN



Stratigraphic Column after Rosenshein, 1962

Stratigraphic Column after Brown and Thompson, 2005

TABLE 1

Comparison of Surface Water and Ground Water Elevations

TABLE 1

GARY DEVELOPMENT LANDFILL
Comparison of Static Ground Water and Surface Water Elevations in the Grand Calumet River

Well ID	C-5	C-10	C-12	RIVER	
Well Depth (ft)	5.7'	4.3'	20.0'		
Datum Ele (ft)	585.47'	584.18'	584.23'	580.00'	
Location	3,000' west	3,000' west	3,000' west	1.5 mi east	
DATE	**WATER ELEVATION (Datum Elevation minus Height)**				**FLOW DIRECTION**
10/8/2009	585.47 - 1.0 = 584.47	584.18 - 1.61 = 582.57	584.23 - 1.72 = 585.51	580.00 - 1.99 = 581.99	To river
5/20/2009	585.47 - .82 = 586.29	584.18 - .94 = 583.24	584.23 - .89 = 583.34	580.00 - 3.58 = 583.58	To Aquifer
11/19/2008	585.47 - .04 = 585.51	584.181 - .07 = 583.11	584.23 - 1.2 = 583.03	580.00 - 1.01 = 581.01	To River
7/2/2008	585.47 - .47 = 585.00	584.18 - 2.68 = 581.15	584.23 - .97 = 583.26	580.00 - 3.38 = 583.38	Mixed

Note: during normal river stage, gw discharges to the river. During higher river (flooding) stages, flow reverses such that surface water infiltrates the aquifer. Comparison of river stage data with precip data obtained from TS480 (Chesterson) suggests river stage is primarily affected by influent than precip.

APPENDIX 1

Boring Logs

ATEC Associates, Inc.
5150 East 65th Street
Indianapolis, Indiana 46220
317-849-4990

Corporate Office:
Indianapolis, IN

District Offices:
Atlanta, GA
~~Baltimore, MD~~
Birmingham, AL
~~Cincinnati, OH~~
Dallas, TX
Denver, CO
Fort Myers, FL
Freeport, TX
Houston, TX
Huntsville, Al
Kansas City, KS
Lexington, KY
Louisville, KY
Salisbury, MD
Savannah, GA
Washington, DC
York, PA

District Affiliates:
Beckley, WV
Norkfolk, VA

June 24, 1981

Reid, Quebe, Allison, Wilcox & Associates, Inc.
120 W. LaSalle Street
Suite 606
South Bend, Indiana 46601

Attention: Mr. Dennis M. Neidigh, P.E.
Project Director

Re: Geotechnical Investigation
Final Report
Milepost 10-SR 912 South Interchange
Indiana Toll Road Improvement
Gary, Indiana
ATEC Associates Project 21-03189-10

Gentlemen:

Submitted herewith is our final report for the geotechnical engineering study conducted for the 1980 improvements to the East-West Indiana Toll Road. This report pertains specifically to Milepost 10. This study was conducted in accordance with our agreement with the Indiana Toll Road Commission dated October 10, 1980.

This report contains the findings of our field and laboratory studies, and an engineering interpretation of the existing conditions as they pertain to the proposed toll road improvements. Recommendations are provided to aid in the design of foundations or other earth-related components.

We appreciate the opportunity to be of service to you on this project. If we can be of any further assistance, please contact this office.

Very truly yours,

ATEC Associates, Inc.

M. Surendra

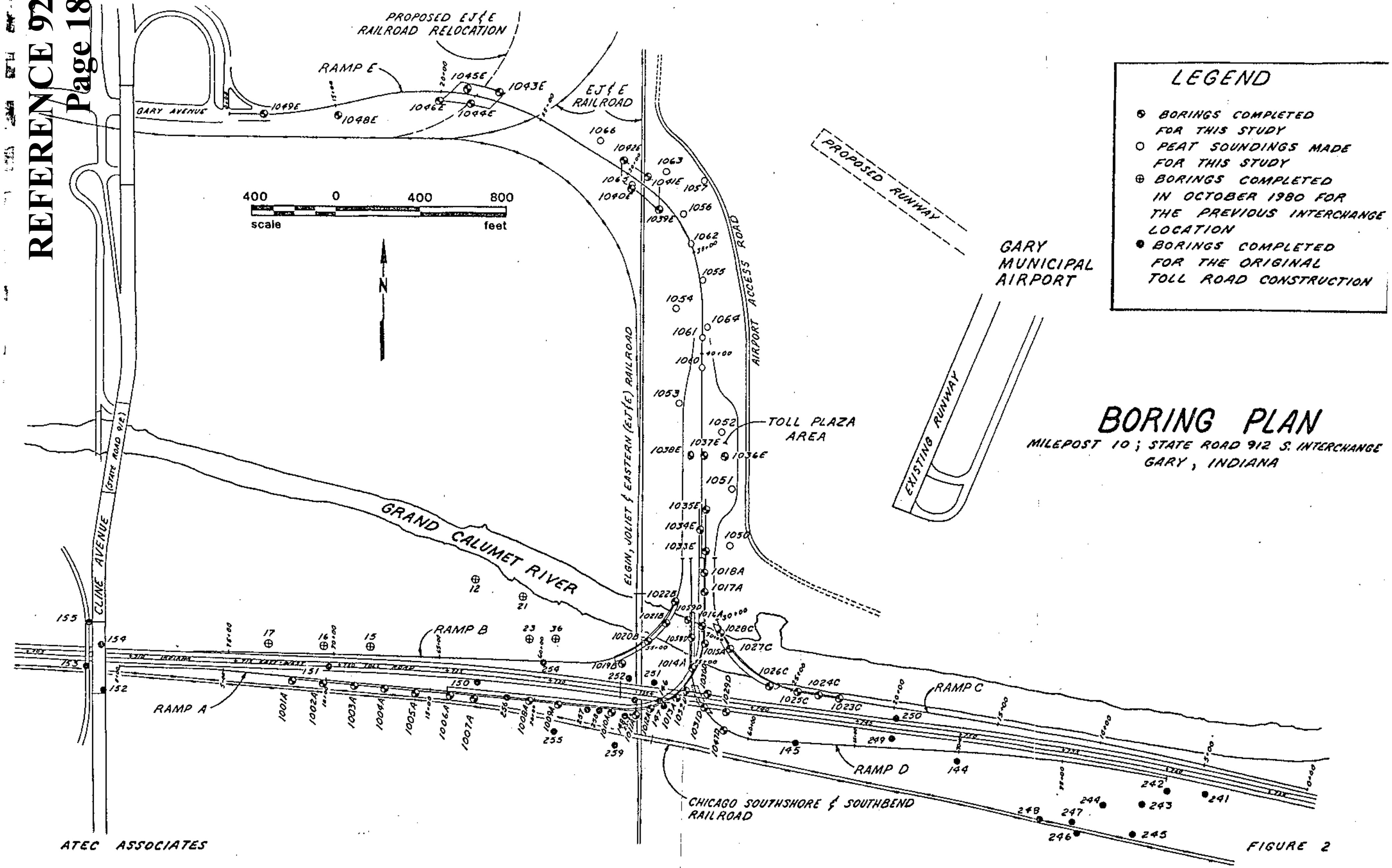
M. Surendra, Ph.D.
Staff Engineer

William A. Cutter

William A. Cutter, P.E.
Senior Project Engineer
Project Coordinator

WILLIAM A. CUTTER
REGISTERED
NO.
13316
STATE OF
INDIANA
PROFESSIONAL ENGINEER

bl/TOLL4:V
Copies: (5) RQAW, South Bend
(1) Lawson-Fisher Associates



BORING PLAN
MILEPOST 10; STATE ROAD 912 S. INTERCHANGE
GARY, INDIANA

FIGURE 2

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1010A

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 733+28; 116' Rt.
FOREMAN D. White
INSPECTOR -

JOB NO. 21-03189-10
DATE 03-12-81
BORING METHOD CA/RC
ROCK CORE DIA. 2.0 IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
SURFACE ELEVATION 591.1							
TOPSOIL	0.4						
Brown to Dark Brown slightly moist medium dense fine SAND (SP) with trace Silt			1	9 11/13	75		**Soil classification by Textural Classification System
(SAND)**	5.5	5	2	4 6/12	50		
Brown wet dense fine SAND (SP) with trace Silt			3	11 18/28	50		
(SAND)**		10	4	9 18/22	50		
	12.0						
Gray moist very dense fine SAND (SP) with trace Silt		15	5	18 24/31	75		
(SAND)**		20	6	23 36/45	75		
	22.0						
Gray wet very dense SILTY fine SAND (SM)		25	7	26 44/40	100		
(SANDY LOAM)**		30	8	16 27/34	100		
	31.5						
Gray moist medium dense fine SAND (SP) with trace Silt							
(SAND)**	35.5	35	9	18 18/10	100		
Gray moist stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel			10	5 6/7	100		
(CLAY)**		40					

WATER LEVEL OBSERVATIONS
NOTED ON RODS - FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1010A

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 733+28; 116' Rt.
FOREMAN D. White
INSPECTOR

JOB NO. 21-03189-10
DATE 03-12-81
BORING METHOD CA/RC
ROCK CORE DIA. 2.0 IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 591.1)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN. THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist stiff to very stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**		40	11	5 7/9	100		**Soil classification by Textural Classification System
		45	12	4 5/7	100		
		50	13	4 5/7	100		
		55	14	4 7/7	100		
Gray moist stiff to medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**	59.5	60	15	4 4/7	100		Borehole advanced using rotary drilling technique below 60.0'
		65	16	3 4/7	100		
		70	17	4 4/5	100		
		75	18	7 7/9	100		
Gray slightly moist hard SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel (CLAY)**	78.5	80					

WATER LEVEL OBSERVATIONS
NOTED ON RODS - FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA—HOLLOW STEM AUGER
CFA—CONTINUOUS FLIGHT AUGER
DC —DRIVEN CASING
MD —MUD DRILLING
RC —ROCK CORING
CA —CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.

Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1010A

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 733+28; 116' Rt.
FOREMAN: D. White
INSPECTOR: -

JOB NO. 21-03189-10
DATE: 03-12-81
BORING METHOD: CA/RC
ROCK CORE DIA. 2.0 IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION: 591.1

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS (STD. PENETRATION)	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray slightly moist hard SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel (CLAY)**		80	19	8 16/21	100		**Soil classification by Textural Classification System
	85.1		20	50 / 0.1	0		
Gray, slightly weathered, with a little solutioning, hard, very close to closely jointed, fine grained to crystalline dolomitic LIMESTONE with oil - tar filled cavities		85 / 90		RC Run No. 1	83		Rock Core Run #1: 85.1' to 95.1' RQD = 34%
Bottom of Test Boring @ 95.1'		95					

WATER LEVEL OBSERVATIONS
NOTED ON RODS - FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1022B

Page 1 of 3

CLIENT: Indiana Toll Road Commission
JOB NO.: 2103189-10
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
DATE: 3/28/81
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING METHOD: HSA
BORING LOCATION: Station 735+75; 460' Lt.
ROCK CORE DIA.: - IN.
FOREMAN: R. Groves/K. Cardinal
SHELBY TUBE DIA.: - IN.
INSPECTOR: -

SURFACE ELEVATION: 584.2

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Brown dry very loose organic SILTY SAND (SM) (SANDY LOAM)**	3.0		1	1 1/1	10		**Soil classification by Textural Classification System
Gray wet loose fine SAND (SP) with trace Silt (SAND)**		5	2	4 5/5	80		
			3	2 3/3	70		
		10	4	3 5/4	70		
		15	5	4 4/8	40		
		20	6	5 6/12	100		
		25	7	8 10/14	100		
	28.5						
Wood layer	30.0	30	8	10 10/12	60		
Gray moist very stiff SILTY CLAY (CL) with trace fine to coarse Sand and Gravel		35	9	8 10/10	100		Borehole advanced using rotary drilling technique below 35.0 ft.
		40	10	8 11/14	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 3.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1022B

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 735+75; 460' Lt.
FOREMAN R. Groves/K. Cardinal
INSPECTOR -

JOB NO. 2103189-10
DATE 3/28/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION 584.2

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION SAMPLE NO.	BLOWS/6 IN. THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**		45	11	4 4/5	100		**Soil classification by Textural Classification System
		50	12	3 4/4	100		
	52.0						
Gray moist very stiff SILT (ML) with a little Clay (SILT)**		55	13	13 14/13	80		
	56.0						
Gray moist stiff to very stiff SILTY CLAY (CL) with a little fine to coarse Sand and trace Gravel (CLAY)**		60	14	5 6/7	100		
		65	15	5 5/7	100		
		70	16	6 7/8	100		
		75	17	6 9/11	40		Two attempts were made to recover Sample No. 17.
	77.0						
Gray moist very stiff SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel with some very thin Silt seams (CLAY)**		80	18	8 10/13	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 3.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1022B

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 735+75; 460' Lt.
FOREMAN R. Groves/K. Cardinal
INSPECTOR -

JOB NO. 2103189-10
DATE 3/28/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION 584.2

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist very dense SILTY CLAY (CL) with little fine Sand and fine Gravel (CLAY)**	82.0						**Soil classification by Textural Classification System
Gray slightly moist hard SILTY CLAY (CL) with some fine to coarse Sand and trace Gravel (CLAY)**	88.0	85	19	25 40/50 0.3	100		
Gray slightly moist hard SILTY SAND (SM) with little clay (SANDY LOAM)**	89.6	90	20	39 50/0.2	100		[c]Borehole caved to 4.0' upon completion.
Gray slightly moist hard SANDY SILT (ML) with little Clay (SILTY LOAM)**		95					
Bottom of Test Boring @ 93.2'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 3.5 FT.
AT COMPLETION - FT. c
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1039E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 733+75; 2290' Lt.
FOREMAN R. Hackman
INSPECTOR M. Surendra

JOB NO. 2103189-10
DATE 4/2/81
BORING METHOD HSA
ROCK CORE DIA. – IN.
SHELBY TUBE DIA. – IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 589.6)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN; THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Brown moist loose to medium dense fine SAND (SP) with trace Silt (SAND)**			1	1 3/3	100		**Soil classification by Textural Classification System
-wet below 6.0'		5	2	4 5/6	100		
			3	3 3/4	80		Introduced water below 7.5 ft to maintain a stable hole
		10	4	3 4/7	100		
Gray wet dense fine SAND (SP) with trace Silt and trace Shells (SAND)**	13.0	15	5	9 19/23	80		
		20	6	9 21/40	100		
		25	7	8 26/42	100		
		30	8	12 28/38	100		
		35	9	9 13/18	60		
Gray moist SILTY CLAY (CL) with trace fine Sand and trace Shells (CLAY)**	39.0	40	10	3 3/4	100		Two samples taken

WATER LEVEL OBSERVATIONS
NOTED ON RODS 7.5 FT.
AT COMPLETION – FT.
AFTER – HRS. – FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1039E
Page 2 of 3

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 733+75; 2290' Lt.
FOREMAN: R. Hackman
INSPECTOR: M. Surendra

JOB NO. 2103189-10
DATE 4/2/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 589.6)	STRATUM DEPTH, FT.	DEPTH, FT.	SAMPLE NO.	BLOWS/6 IN.; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist soft to medium stiff SILTY CLAY (CL) with trace fine Sand and trace Shells and trace Gravel			11	3 5/5	100		
(CLAY)**		45	12	3 3/5	100		Borehole advanced using rotary drilling technique below 45.0'
		50	13	2 4/4	100		
		55	14	3 5/5	100		**Soil classification by Textural Classification System
		60	15	3 4/5	100		
	66.0	65	16	2 3/3	100		
Gray slightly moist soft SILTY CLAY (CL) with trace fine Sand and trace Gravel			17	2 3/5	100		Sampler was sunk from 66.0 to 66.5 ft under its own weight.
-moist below 68.0'			18	3 4/5	100		
(CLAY)**		70					
-some fine to medium Sand from 74.5 to 75.0'		75	19	3 4/4	100		
		80	20	6 5/6	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 7.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1039E

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 733+75; 2290' Lt.
FOREMAN: R. Hackman
INSPECTOR: M. Surendra

JOB NO. 2103189-10
DATE 4/2/81
BORING METHOD HSA
ROCK CORE DIA. – IN.
SHELBY TUBE DIA. – IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 589.6)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN. THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist meduim stiff SILTY CLAY (CL) with trace to some fine Sand and trace Gravel (CLAY)**		85	21	4 4/8	100		**Soil classification by Textural Classification System
	90.5	90	22	5 7/10	100		
Gray slightly moist hard SILTY CLAY (CL) with trace Sand and trace Gravel (CLAY)**		95	23	18 26/32	100		
		100	24	20 35/38	100		
		105	25	15 20/33	60		
		110	26	22 20/30	100		
Bottom of Test Boring @ 110.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 7.5 FT.
AT COMPLETION – FT.
AFTER – HRS. – FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1040E

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 732+50; 2380' Lt.
FOREMAN: R. Hackman
INSPECTOR: A. Spencer

JOB NO. 2103189-10
DATE 4/10/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 584.6)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Dark Brown moist loose SILTY organic SAND (SM) with roots (SANDY LOAM)**	1.5		1	2 3/4	80		Two samples taken
Brownish Gray wet loose fine to medium SAND (SP) with trace Silt (SAND)**		5	2	2 2/4	100		**Soil classification by Textural Classification System
	8.0		3	3 3/5	100		
Gray wet dense to very dense SAND (SM) with little Silt -very thin wood seam at 9.5' (SANDY LOAM)**		10	4	12 16/25	100		
		15	5	15 38/50 0.4	100		
		20	6	17 28/33	100		
	27.0	25	7	15 23/28	100		
Gray wet medium dense very fine SAND (SM) with little Silt (SANDY LOAM)**	32.5	30	8	8 12/17	75		
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace small Gravel (CLAY)**		35	9	3 3/4	90		
Bottom of Test Boring @ 35.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 1.0 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.

Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1046E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 723+00; 2751' Lt.
FOREMAN R. Hackman
INSPECTOR A. Spencer

JOB NO. 2103189-10.
DATE 4/7/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 586.7)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	BLOWS/6 IN.; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray dry very stiff ash with some slag cobbles (FILL)	2.0		1	4 50/0.2	80		**Soil classification by Textural Classification System
Tan dry medium dense fine SAND (SP) with trace Silt (SAND)**		5	2	4 5/7	100		
			3	4 9/13	100		
	12.0	10	4	5 7/8	100		
Gray wet dense to medium dense fine SAND (SP) with trace Silt (SAND)**		15	5	8 17/21	100		
	562.5 24.2	20	6	3 5/12	100		
Gray wet very dense fine to coarse SAND (SP) with trace Silt and trace Gravel (SAND)**	24.8	25	7	14 29/37	100		Two samples taken.
Gray wet medium dense fine SAND (SP) with trace Silt (SAND)** -thin fine to coarse Sand seam at 29.0 to 29.2'	33.0	30	8	8 11/18	100		
Gray and Brown wet loose fine to coarse SAND (SP) with little Gravel (SAND)**	36.0	35	9	8 3/3	35		
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**			10	3 3/4	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.0 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1046E

CLIENT: Indiana Toll Road Commission
JOB NO. 2103189-10
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
DATE: 4/7/81
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING METHOD: HSA
BORING LOCATION: Station 723+00; 2751' Lt.
ROCK CORE DIA.: - IN.
FOREMAN: R. Hackman
SHELBY TUBE DIA.: - IN.
INSPECTOR: A. Spencer

SURFACE ELEVATION: 586.7

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN; THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand (CLAY)**			11	3 4/5	100		**Soil classification by Textural Classification System
	44.8	45	12	4 4/5	100		
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**	48.0						
Gray moist medium stiff SILTY CLAY (CL) with trace fine Sand (CLAY)**		50	13	3 5/5	80		
	52.5						
Gray moist stiff to medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace small Gravel (CLAY)**		55	14	4 5/7	100		
		60	15	4 4/5	100		
-two thin Silty Sand seams from 64.0 to 64.4'		65	16	4 6/6	100		
		70	17	4 4/5	100		
		75	18	4 4/5	100		
		80	19	5 5/7			

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.0 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1046E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 723+00; 2751' Lt.
FOREMAN R. Hackman
INSPECTOR A. Spencer

JOB NO. 2103189-10
DATE 4/7/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION 586.7

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**	80.5						
Gray moist stiff to very stiff SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel (thin fine to coarse Sand seams from 83.5 to 84.0 ft) (CLAY)**	84.0	85	20	9 9/12	100		Two samples taken.
Gray moist very stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**	87.0	90	21	17 23/24	80		**Soil classification by Textural Classification System
Gray slightly moist hard CLAYEY SILT (CL-ML) with some fine to coarse Sand and trace Gravel (SILTY CLAY)**	92.0	95	22	18 22/27	100		
Gray slightly moist hard SILTY CLAY (CL) with some fine to coarse Sand and trace Gravel (CLAY)**							
Bottom of Test Boring @ 95.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.0 FT.
AT COMPLETION - FT.
AFTER - HRS - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1049E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 714+80; 2640' Lt.
FOREMAN R. Hackman
INSPECTOR A. Spencer

JOB NO. 2103189-10
DATE 4/8/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 586.1)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
TOPSOIL 0.1' Tan dry loose to medium dense fine SAND (SP) with trace Silt (SAND)**			1	2 2/2	100		**Soil classification by Textural Classification System
		5	2	3 4/4	100		
			3	4 7/8	100		
	9.5	10	4	4 9/11	100		Two samples taken.
Gray moist to wet very dense very fine SAND (SP) with trace Silt (SAND)**		15	5	12 20/32	100		
		20	6	15 35/45	100		ᶜBorehole caved to 10 ft upon completion.
Bottom of Test Boring @ 20.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.2 FT.
AT COMPLETION - FT. C
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

APPENDIX 2

USGS National Water Information System: Web Interface
Stream Flow Statistics
And
Ground-water levels for the Nation
Tables

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Water-Data Report 2008

04092677 GRAND CALUMET RIVER AT INDUSTRIAL HWY AT GARY, IN

Lake Michigan Basin

LOCATION.--Lat 41°36'28", long 87°23'37" referenced to North American Datum of 1927, in NW ¼ NW ¼ sec.6, T.36 N., R.8 W., Lake County, IN, Hydrologic Unit 04040001, on left bank, 30 feet upstream of U.S. 12 (Industrial Highway), 100 feet streamward of the centerline of Interstate 90, 2,000 feet downstream of Norfolk and Western railroad bridge, 6,000 feet southeast of Gary Airport terminal.

DRAINAGE AREA.--Indeterminate.

SURFACE-WATER RECORDS

PERIOD OF RECORD.--October 1991 to September 1994, (gage heights only), October 1994 to May 2001, December 2001 to current year.

GAGE.--Water-stage recorder and Acoustic Doppler Velocity Meter. Datum of gage is 580.00 ft above National Geodetic Vertical Datum of 1929.

REMARKS.--Records good except for estimated daily discharges, which are fair. Discharge is primarily from industrial and city effluent.

04092677 GRAND CALUMET RIVER AT INDUSTRIAL HWY AT GARY, IN—Continued

**DISCHARGE, CUBIC FEET PER SECOND
WATER YEAR OCTOBER 2007 TO SEPTEMBER 2008
DAILY MEAN VALUES**
[e, estimated]

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	471	458	443	452	e485	475	494	483	566	504	547	486
2	454	459	458	454	473	482	477	490	556	496	538	495
3	464	458	448	463	469	500	473	498	567	502	532	489
4	464	455	440	463	476	488	472	493	562	496	538	557
5	462	e459	e425	472	497	490	470	487	596	499	663	605
6	468	453	451	474	523	480	464	487	575	499	575	539
7	466	446	449	478	504	470	465	501	563	492	549	522
8	462	448	e442	583	498	473	466	498	580	498	541	542
9	463	451	436	535	510	467	485	491	576	526	542	552
10	460	453	441	541	503	466	471	494	555	497	543	522
11	453	e455	470	545	500	472	497	530	528	509	545	509
12	455	445	479	526	489	465	491	536	537	498	540	518
13	456	450	473	519	487	463	487	531	541	497	544	712
14	443	451	470	505	476	469	485	532	532	504	537	773
15	446	439	458	508	474	473	492	523	532	517	544	721
16	453	444	461	496	479	474	480	533	532	513	540	680
17	456	449	456	495	521	476	479	539	528	508	529	635
18	480	443	451	497	510	484	478	539	525	515	519	634
19	454	447	453	488	503	482	486	533	522	541	524	625
20	445	452	455	487	487	477	492	525	528	549	523	605
21	442	477	460	487	485	471	485	538	522	501	509	590
22	436	466	e477	489	479	475	486	555	526	509	498	586
23	448	450	479	485	484	473	483	558	523	524	510	585
24	433	446	464	477	483	468	478	573	524	534	493	569
25	435	443	456	481	483	474	482	577	530	528	496	573
26	456	432	448	472	e475	483	495	577	515	530	502	571
27	462	436	455	477	471	481	482	563	513	523	497	572
28	454	440	462	481	471	495	e488	575	514	522	494	561
29	457	442	470	490	469	491	492	583	511	527	494	569
30	465	436	e466	499	---	488	478	581	502	534	489	558
31	460	---	465	478	---	491	---	574	---	541	489	---
Total	14,123	13,483	14,161	15,297	14,164	14,816	14,453	16,497	16,181	15,933	16,384	17,455
Mean	456	449	457	493	488	478	482	532	539	514	529	582
Max	480	477	479	583	523	500	497	583	596	549	663	773
Min	433	432	425	452	469	463	464	483	502	492	489	486

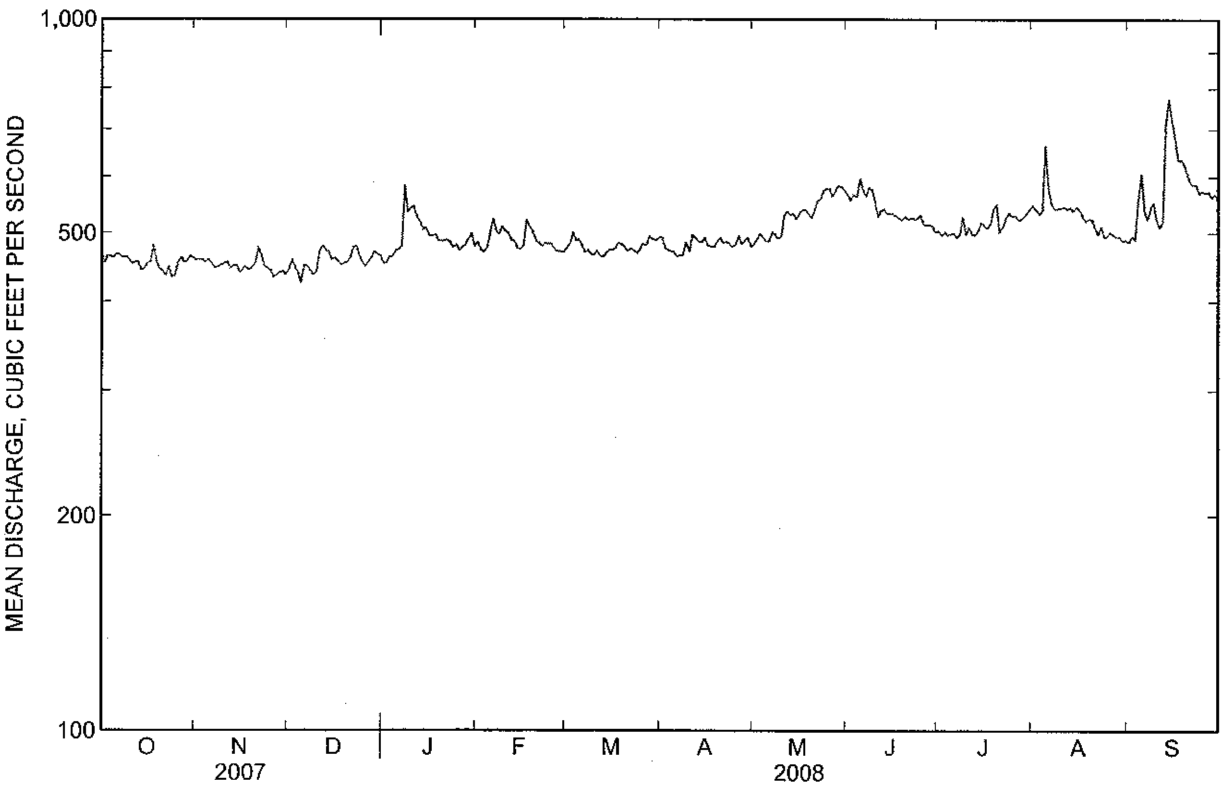
STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1995 - 2008, BY WATER YEAR (WY)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	499	478	455	448	459	474	498	519	532	529	529	526
Max	591	536	523	515	534	548	579	608	662	711	711	625
(WY)	(2003)	(2005)	(2000)	(1999)	(1999)	(1999)	(1999)	(2002)	(2002)	(2002)	(2003)	(2002)
Min	368	374	349	363	374	402	381	400	459	434	422	398
(WY)	(2006)	(2006)	(2006)	(2006)	(2007)	(2006)	(1996)	(1996)	(1995)	(1995)	(2005)	(2005)

04092677 GRAND CALUMET RIVER AT INDUSTRIAL HWY AT GARY, IN—Continued

SUMMARY STATISTICS

	Calendar Year 2007		Water Year 2008		Water Years 1995 - 2008	
Annual total	167,971		182,947			
Annual mean	460		500		496	
Highest annual mean					556	2002
Lowest annual mean					426	2006
Highest daily mean	674	Aug 23	773	Sep 14	783	Jul 27, 2003
Lowest daily mean	355	Feb 15	425	Dec 5	305	Apr 27, 1996
Annual seven-day minimum	361	Feb 14	439	Nov 25	339	Dec 20, 2005
Maximum peak flow			890	Sep 14	1,130	Jul 27, 2003
Maximum peak stage			5.46	Sep 14	5.46	Sep 14, 2008
10 percent exceeds	541		561		589	
50 percent exceeds	454		489		489	
90 percent exceeds	396		451		416	



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National Water Information System: Web Interface

USGS Water Resources (Cooperator Access)

Data Category: Real-time

Geographic Area: Indiana

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News - updated January 2010

NOTE:USGS Indiana historic, recent, and real-time data will continue to be provided in Eastern Standard Time.

Flow-duration tables and other streamflow statistics for selected gaging stations are available on another web page by clicking this link!

NOTE: During winter months, stage and discharge may be affected by ice. Click here for more information.

USGS 04092677 GRAND CALUMET RIVER AT INDUSTRIAL HWY AT GARY, IN

PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site Time-series: Real-time data GO

This gaging station is maintained in cooperation with:

- **The Indiana Department of Environmental Management**

National Weather Service River Forecasts

This station managed by the Indiana Water Science Center Office.

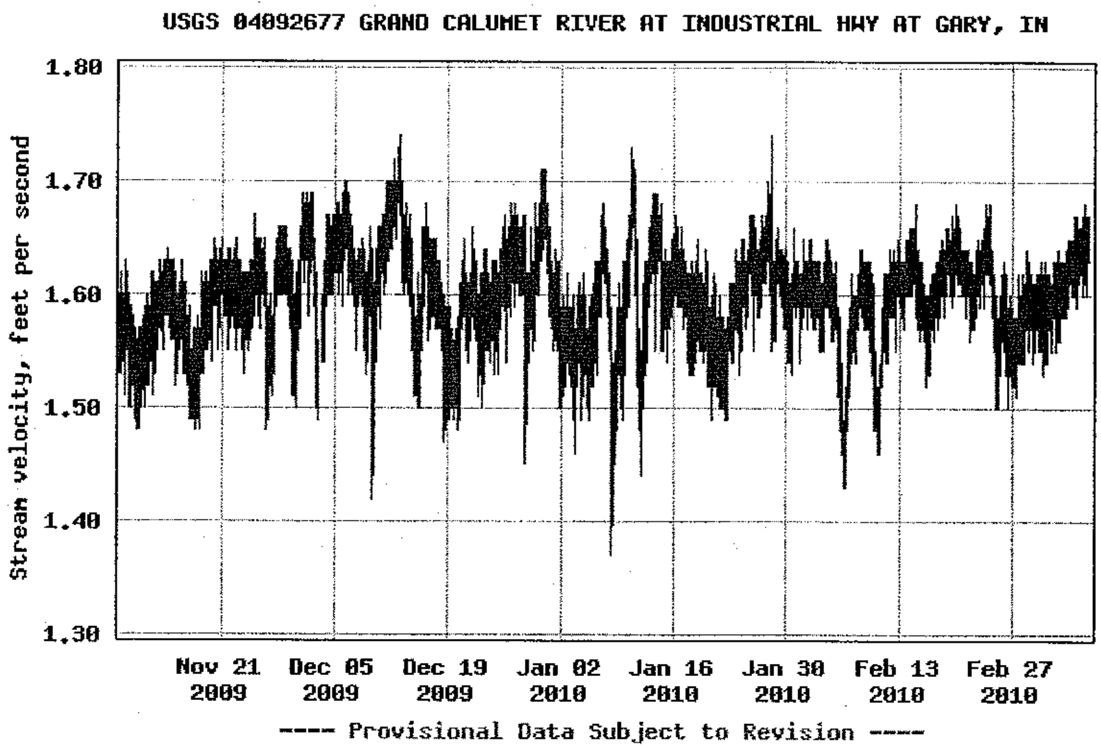
Available Parameters	Output format	Days	
☑ All 3 Available Parameters for this site ☑ 00055 Stream velocity ☑ 00065 Gage height	◉ Graph ○ Graph w/ stats ○ Graph w/o stats ○ Table	120 (1-120)	GO

☑ 00060 Discharge	○ Tab-separated		

Summary of all available data for this site

Stream velocity, feet per second

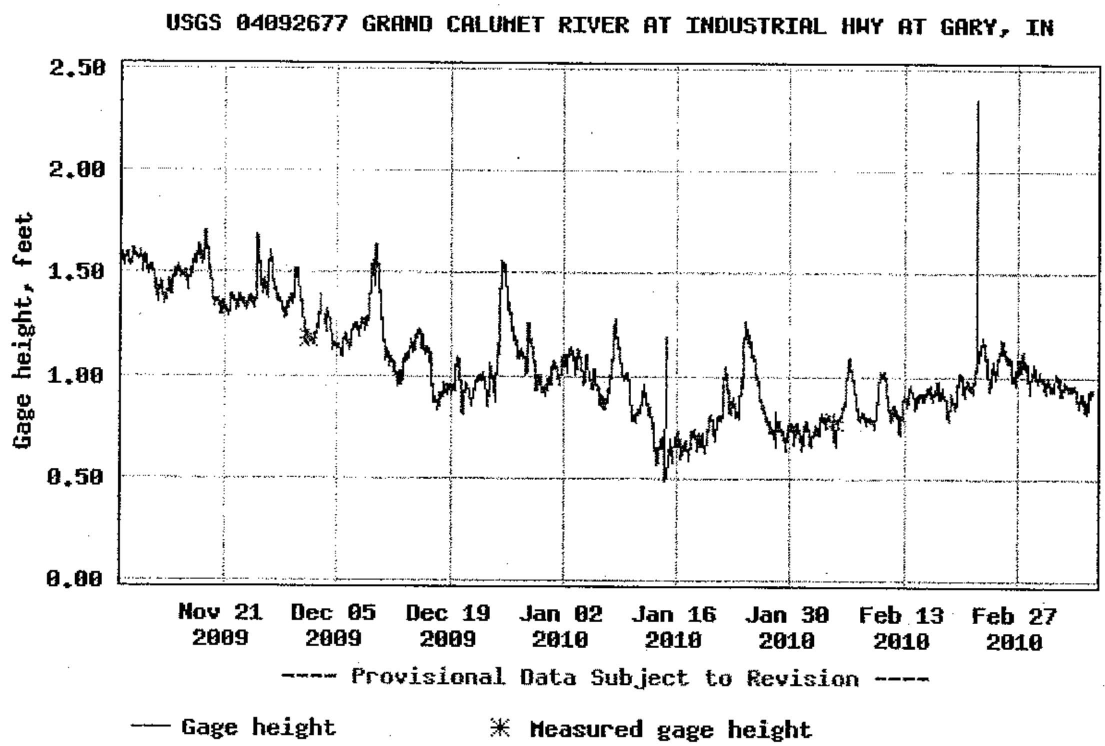
Most recent instantaneous value: 1.64 03-08-2010 07:50 EST



Create presentation-quality / stand-alone graph parm 00055 DD01

Gage height, feet

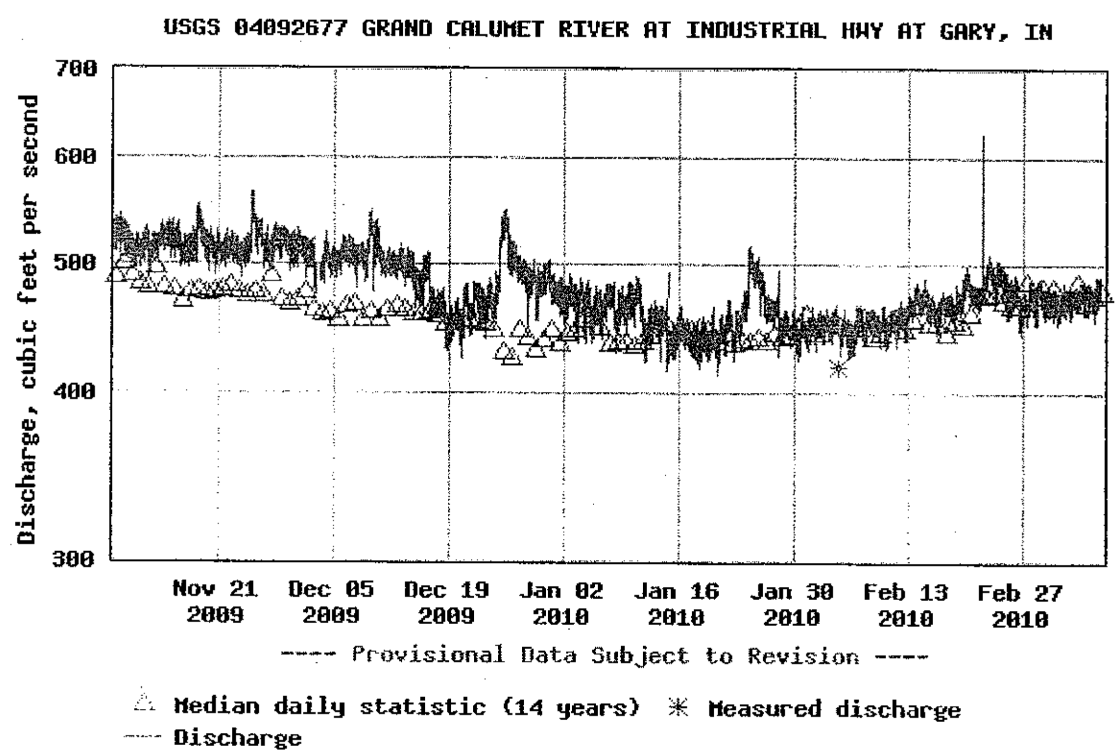
Most recent instantaneous value: 0.92 03-08-2010 07:50 EST



Create presentation-quality / stand-alone graph parm 00065 DD02

Discharge, cubic feet per second

Most recent instantaneous value: 478 03-08-2010 07:50 EST



Create presentation-quality / stand-alone graph parm 00060 DD03

Daily discharge statistics, in cfs, for Mar 8 based on 14 years of record more

Min (2006)	20th percen-tile	Mean	Median	Most Recent Instantaneous Value	80th percen-tile	Max (1998)
384	404	467	476	478	525	546

Well C-5

National Water Information System: Web Interface

USGS Water Resources (Cooperator Access)

Data Category: Ground Water
Geographic Area: United States
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Ground-water levels for the Nation

Search Results -- 1 sites found

Search Criteria

Agency code =	usgs
site_no list =	• 413655087275202
Minimum number of levels =	1

Save file of selected sites to local disk for future upload

USGS 413655087275202 USGS WELL C-5 DUPONT PROPERTY NORTH (RPD=96)

Lake County, Indiana
Latitude 41°36'55", Longitude 87° 26'20" NAD27
Land-surface elevation 585.47 feet above sea level NGVD29
The depth of the well is 5.7 feet below land surface.
The depth of the hole is 5.7 feet below land surface.
This well is completed in the Other aquifers (N9999OTHER) national aquifer.
This well is completed in the Dune Deposit (110DUNED) local aquifer.

Output formats

Table of data
Tab-separated data
Graph of data
Reselect period

Date	Time	Water level, feet below land surface	Status
1985-10-25		1.89	

Date	Time	Water level, feet below land surface	Status
1991-07-11		2.20	

1985-11-27		0.80	
1985-12-06		0.88	
1986-02-20		0.08	
1986-03-21		0.96	
1986-04-01		1.78	
1986-05-15		1.49	
1986-08-13		2.34	
1986-12-16		1.21	
1987-02-24		1.48	
1987-07-21		2.43	
1987-08-05		2.73	
1987-12-17		0.30	
1988-03-30		0.73	
1988-03-31		0.66	
1988-07-06		3.11	
1989-01-25		1.86	
1989-04-19		1.37	
1989-08-04		2.48	
1990-03-01		1.20	
1990-05-31		1.05	
1990-09-20		1.78	
1990-11-28		-0.26	
1991-03-21		0.35	
1991-10-17		2.26	
1992-01-17		1.46	
1992-04-01		1.11	
1992-06-24		2.48	
1992-09-10		2.66	
1993-03-18	08:51	0.14	
1993-06-10	07:59	-0.91	
1993-09-09	13:23	0.04	
1994-11-09	11:07	0.99	
1995-01-19	15:25	-0.07	
1997-06-27		2.36	
2002-09-05		3.49	
2003-07-09		1.37	
2004-04-07		0.37	
2004-10-27		1.70	
2005-02-16		0.03	
2005-04-20		0.08	
2005-07-20		2.38	
2006-04-05		0.65	
2006-07-10		1.90	
2008-07-02		0.47	
2008-11-19		-0.04	
2009-05-20	14:15	-0.82	
2009-10-08	12:41	1.00	

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National Water Information System: Web Interface

USGS Water Resources (Cooperator Access)

Data Category: Ground Water

Geographic Area: United States

GO

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Ground-water levels for the Nation

Search Results -- 1 sites found

Search Criteria

site_no list =	• 413655087275202
Minimum number of levels = 1	

Save file of selected sites to local disk for future upload

USGS 413655087275202 USGS WELL C-5 DUPONT PROPERTY NORTH (RPD=96)

Available data for this site Ground-water: Field measurements GO

Lake County, Indiana Hydrologic Unit Code 04040001 Latitude 41°36'55", Longitude 87°26'20" NAD27 Land-surface elevation 585.47 feet above sea level NGVD29 The depth of the well is 5.7 feet below land surface. The depth of the hole is 5.7 feet below land surface. This well is completed in the Other aquifers (N9999OTHER) national aquifer. This well is completed in the Dune Deposit (110DUNED) local aquifer.	**Output formats** Table of data Tab-separated data Graph of data Reselect period

REFERENCE 92
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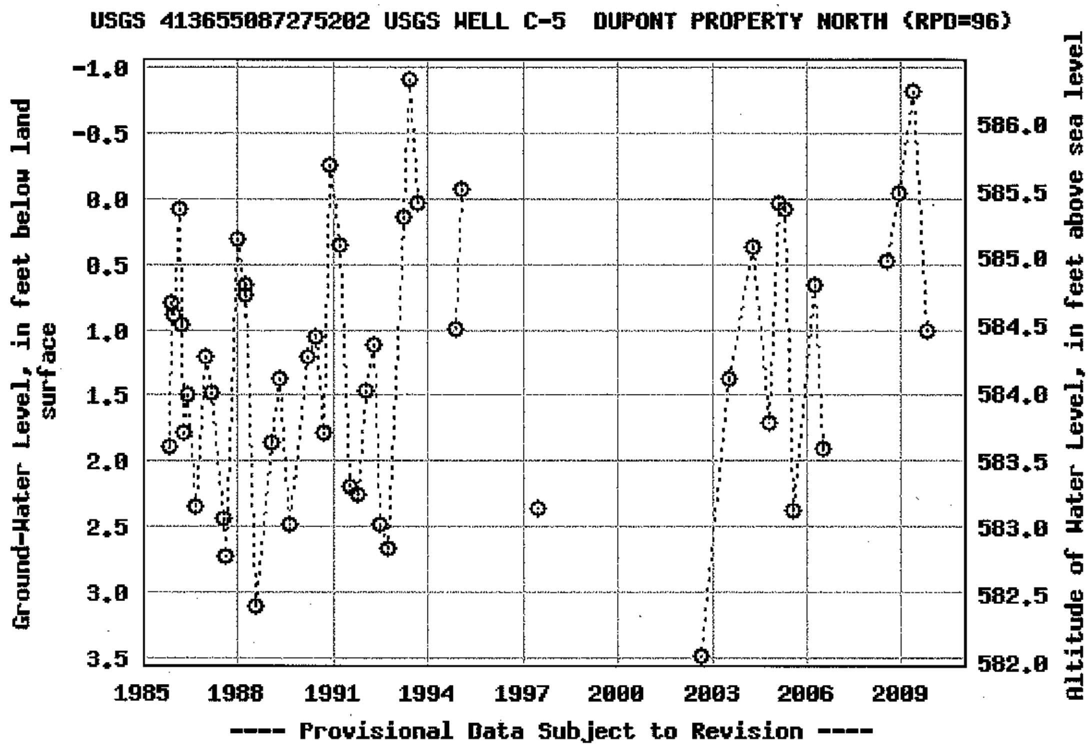

Breaks in the plot represent a gap of at least one year between field measurements.
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U.S. Department of the Interior | U.S. Geological Survey
Title: Ground water for USA: Water Levels
URL: http://waterdata.usgs.gov/nwis/gwlevels?

USA.gov
TAKE PRIDE IN AMERICA

Page Contact Information: Water-Data Support Team
Page Last Modified: 2010-03-08 11:53:30 EST
2.06 2.03 nadww01

REFERENCE 92
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National Water Information System: Web Interface

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Ground-water levels for the Nation

Search Results -- 1 sites found

Search Criteria

Agency code =	usgs
site_no list =	• 413652087274901
Minimum number of levels =	1

Save file of selected sites to local disk for future upload

USGS 413652087274901 USGS WELL C-10 DUPONT PROPERTY MIDDLE (RPD=24)

Lake County, Indiana
Latitude 41°36'49.87", Longitude 87°26'22.11" NAD83
Land-surface elevation 584.18 feet above sea level NGVD29
The depth of the well is 4.3 feet below land surface.
The depth of the hole is 36.00 feet below land surface.
This well is completed in the Other aquifers (N9999OTHER) national aquifer.
This well is completed in the Dune Deposit (110DUNED) local aquifer.

Output formats

Table of data
Tab-separated data
Graph of data
Reselect period

Date	Time	Water level, feet below land surface	Status
1985-10-25		1.22	

Date	Time	Water level, feet below land surface	Status
1995-01-19	14:40	0.87	

1985-11-27		-0.01		1995-11-29		1.53	
1985-12-06		0.77		1996-03-28		1.52	
1985-12-18		0.92		1997-04-02		1.01	
1986-01-08		1.01		1997-06-27		2.22	
1986-02-04		0.50		1997-12-12		1.22	
1986-02-20		0.69		1998-03-24		0.88	
1986-03-07		0.77		1998-07-14		2.08	
1986-03-21		0.86		1998-12-15		2.01	
1986-04-01		0.88		1999-03-02		1.35	
1986-05-15		0.97		1999-06-30		1.65	
1986-08-13		1.38		1999-08-31		3.02	
1986-12-16		0.89		2000-01-04		2.42	
1987-02-24		1.06		2000-03-28		2.10	
1987-07-21		1.83		2000-06-27		1.50	
1987-08-05		1.96		2000-08-29		3.29	
1987-12-17		0.98		2001-02-27		1.02	
1988-03-30		0.65		2001-04-12		1.29	
1988-07-06		2.81		2001-06-06		1.06	
1988-10-13		2.85		2001-09-05		3.26	
1989-01-25		1.32		2001-12-12		1.61	
1989-04-19		1.18		2002-03-26		1.38	
1989-08-04		2.04		2002-09-05		3.06	
1990-03-01		1.15		2003-04-08		1.68	
1990-05-31		1.15		2003-07-09		1.90	
1990-09-20		1.57		2004-01-06		1.58	
1990-11-28		0.27		2004-04-07		2.41	
1991-03-21		0.81		2004-10-27		2.08	
1991-07-11		1.80		2005-02-16		0.78	
1991-10-17		1.77		2005-04-20		1.23	
1992-01-17		1.29		2005-07-20		2.98	
1992-04-01		1.07		2006-04-05		2.46	
1992-09-10		1.47		2006-07-10		3.30	
1992-10-05		2.37		2006-10-03		1.62	
1993-03-18	08:48	1.11		2007-02-22		1.84	
1993-06-10	07:48	0.69		2007-05-16		1.58	

1993-09-09	13:18	1.06	
1994-11-09	11:03	1.04	

2008-07-02		2.68	
2008-11-19		1.07	
2009-05-20	14:15	0.94	
2009-10-08	12:14	1.61	

Ground-water levels for the Nation

Search Results -- 1 sites found

Search Criteria

Agency code =	usgs
site_no list =	• 413652087274901
Minimum number of levels =	1

Save file of selected sites to local disk for future upload

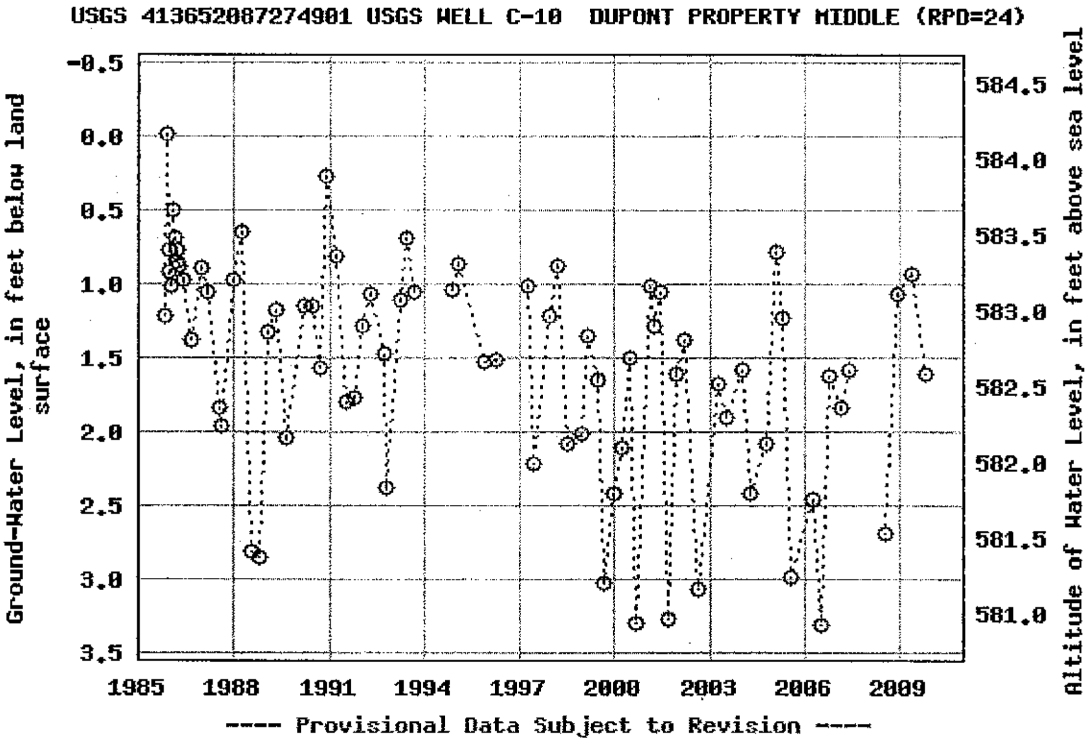
USGS 413652087274901 USGS WELL C-10 DUPONT PROPERTY MIDDLE (RPD=24)

Available data for this site Ground-water: Field measurements GO

Lake County, Indiana
Hydrologic Unit Code 04040001
Latitude 41°36'49.87", Longitude 87°26'22.11" NAD83
Land-surface elevation 584.18 feet above sea level NGVD29
The depth of the well is 4.3 feet below land surface.
The depth of the hole is 36.00 feet below land surface.
This well is completed in the Other aquifers (N9999OTHER) national aquifer.
This well is completed in the Dune Deposit (110DUNED) local aquifer.

Output formats

- Table of data
- Tab-separated data
- Graph of data
- Reselect period



Breaks in the plot represent a gap of at least one year between field measurements.
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USGS Water Resources (Cooperator Access)

Data Category: Ground Water
Geographic Area: United States
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Ground-water levels for the Nation

Search Results -- 1 sites found

Search Criteria

Agency code =	usgs
site_no list =	• 413650087262000
Minimum number of levels =	1

Save file of selected sites to local disk for future upload

USGS 413650087262000 USGS WELL C12 DEEP AT EAST CHICAGO, IN

Lake County, Indiana
Latitude 41°36'49.81", Longitude 87°26'20.53" NAD83
Land-surface elevation 584.23 feet above sea level NGVD29
The depth of the well is 20.0 feet below land surface.
The depth of the hole is 20.00 feet below land surface.
This well is completed in the Other aquifers (N9999OTHER) national aquifer.
This well is completed in the Dune Deposit (110DUNED) local aquifer.

Output formats

Table of data
Tab-separated data
Graph of data
Reselect period

Date	Time	Water level, feet below land surface	Status	Date	Time	Water level, feet below land surface	Status
1987-08-05		1.98		1998-12-15		2.18	

REFERENCE 92
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1988-03-31		0.81	
1988-07-06		2.95	
1988-10-13		2.95	
1989-01-25		1.47	
1989-04-19		1.30	
1989-08-04		2.13	
1990-03-01		1.32	
1990-05-31		1.23	
1990-09-20		1.65	
1990-11-28		0.27	
1991-03-21		0.82	
1991-07-11		1.90	
1991-10-17		1.93	
1992-01-17		1.44	
1992-04-01		1.14	
1992-06-24		2.24	
1992-09-10		1.25	
1992-10-05		2.48	
1993-03-18	08:44	1.19	
1993-06-10	07:45	0.65	
1993-09-09	13:15	1.08	
1994-11-09	11:01	0.98	
1995-01-19	14:37	0.70	
1995-11-29		1.68	
1996-03-28		1.71	
1997-04-02		1.06	
1997-12-12		1.24	
1998-03-24		0.87	
1998-07-14		2.20	
1999-03-02		1.53	
1999-06-30		1.83	
1999-08-31		3.07	
2000-01-04		2.57	
2000-03-28		2.29	
2000-06-27		1.66	
2000-08-29		3.34	
2001-02-27		1.07	
2001-04-12		1.44	
2001-06-06		1.05	
2001-09-05		3.34	
2001-12-12		1.80	
2002-03-26		1.56	
2002-07-10		2.03	
2002-09-05		3.09	
2003-04-08		1.88	
2003-07-09		2.02	
2004-01-06		1.81	
2004-04-07		0.59	
2004-10-27		2.20	
2005-02-16		0.76	
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2005-07-19		2.98	
2006-04-05		1.65	
2006-07-10		1.65	
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2007-05-16		0.02	
2008-07-02		0.97	
2008-11-19		1.20	
2009-05-20	14:14	0.89	
2009-10-08	12:18	1.72	

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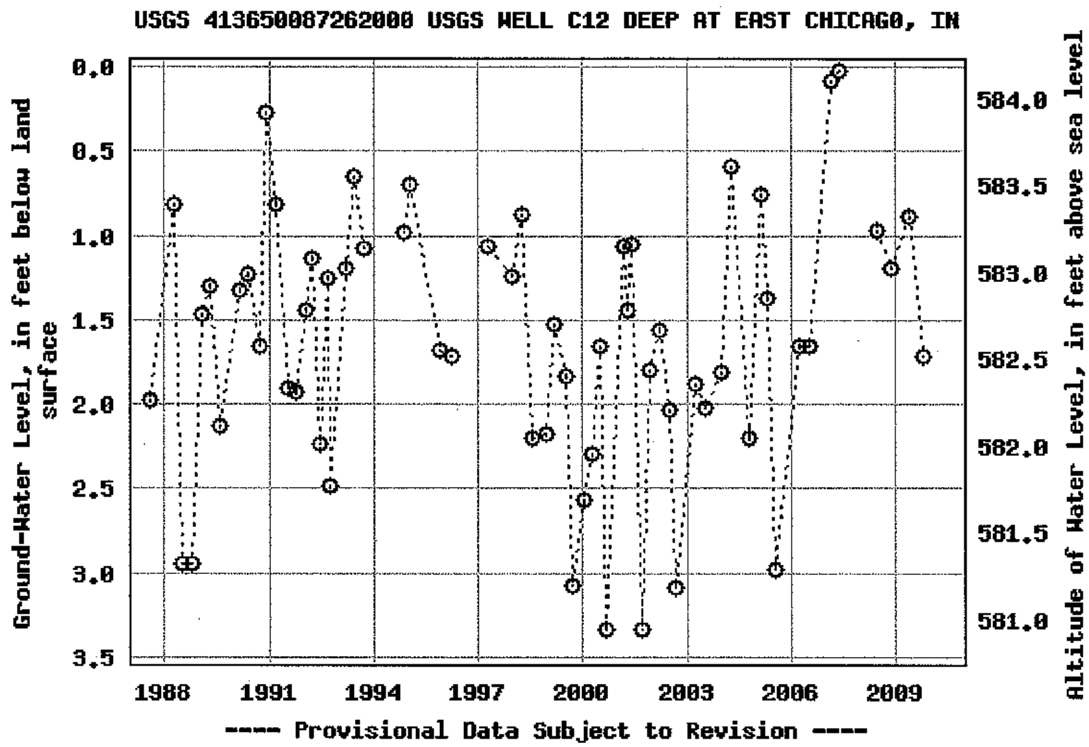

Breaks in the plot represent a gap of at least one year between field measurements.
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URL: http://waterdata.usgs.gov/nwis/gwlevels?

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Search Criteria

site_no list =	• 413655087275202
Minimum number of levels =	1

Save file of selected sites to local disk for future upload

USGS 413655087275202 USGS WELL C-5 DUPONT PROPERTY NORTH (RPD=96)

Available data for this site Ground-water: Field measurements GO

Lake County, Indiana
Hydrologic Unit Code 04040001
Latitude 41°36'55", Longitude 87°26'20" NAD27
Land-surface elevation 585.47 feet above sea level NGVD29
The depth of the well is 5.7 feet below land surface.
The depth of the hole is 5.7 feet below land surface.
This well is completed in the Other aquifers (N9999OTHER) national aquifer.
This well is completed in the Dune Deposit (110DUNED) local aquifer.

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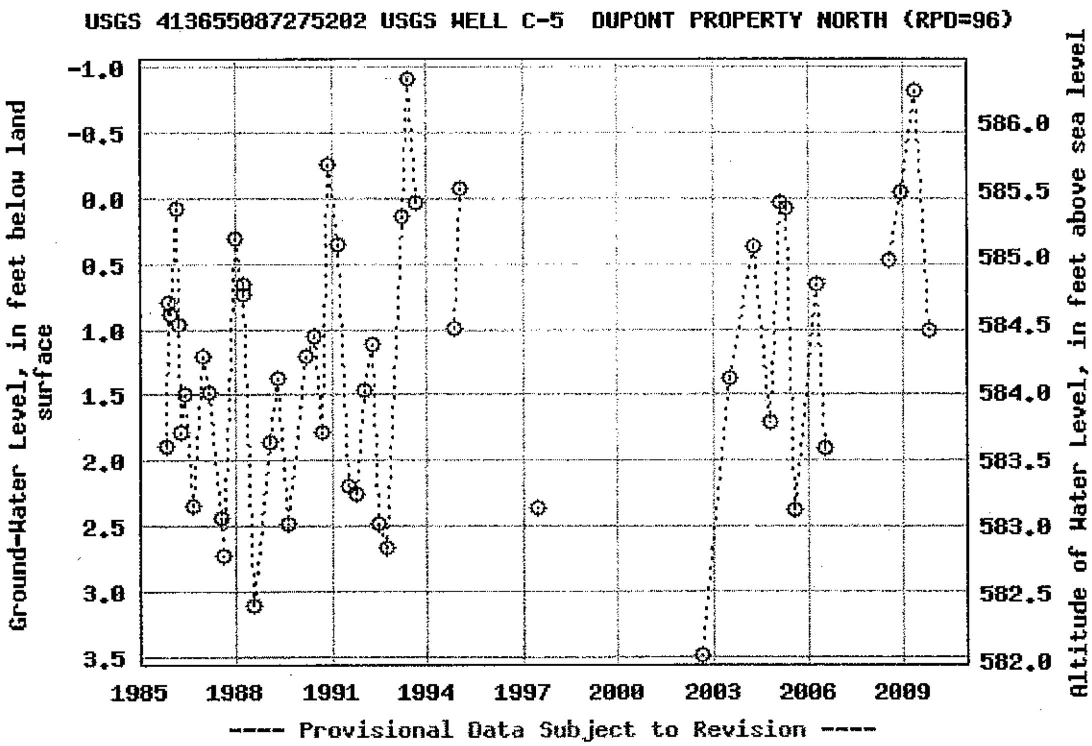

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APPENDIX 3

References

Physiographic Divisions of Indiana

By Henry H. Gray

INDIANA UNIVERSITY
INDIANA GEOLOGICAL SURVEY SPECIAL REPORT 61

BLOOMINGTON, INDIANA: 2000

GEOLOGY OF PLEISTOCENE DEPOSITS OF LAKE COUNTY, INDIANA

By

J. S. Rosenshein

1962

STATE OF INDIANA

DEPARTMENT OF NATURAL RESOURCES

John E. Mitchell, Director

BULLETIN NO. 31

OF THE

DIVISION OF WATER

GEOHYDROLOGY AND GROUND-WATER POTENTIAL OF LAKE COUNTY, INDIANA

BY

J. S. ROSENSHEIN AND J. D. HUNN

GEOLOGISTS, U. S. GEOLOGICAL SURVEY

Prepared by the

GEOLOGICAL SURVEY

UNITED STATES DEPARTMENT OF THE INTERIOR

In cooperation with the

DIVISION OF WATER

DEPARTMENT OF NATURAL RESOURCES

1968

A Report Prepared Under Contract To:

A. T. Kearney, Inc.

Prepared for:

U. S. Environmental Protection Agency
Region V
Chicago, Illinois

INSPECTION OF GROUND-WATER MONITORING PROGRAM
GARY LAND DEVELOPMENT
GARY, INDIANA

Contract No. 68-01-6515
Work Assignment R05-005
Project 02; Task 06

HLA Job No. 6273,042.12

by

for John M. Wilson, CPG
Senior Geohydrologist

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October 12, 1984

transmittal letter

Indiana Department of Highways
Toll Road Division
52551 ash road·post office box 1·granger, indiana 46530-0001·(219)674-8836

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OFFICE OF SOLID AND HAZARDOUS WASTE MGMT DEN

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Indiana Dept. of Environmental Mgm
105 South Meridian
Indianapolis, In. 46206

Date: October 6, 1989
Contract No.

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U.S. Department of the Interior
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Surface-Water and Ground-Water Hydrology and Contaminant Detections in Ground Water for a Natural Resource Damage Assessment of the Indiana Harbor Canal and Nearshore Lake Michigan Watersheds, Northwestern Indiana

By David A. Cohen, Theodore K. Greeman, and Paul M. Buszka

Administrative Report

Prepared for the
U.S. Department of the Interior,
U.S. Fish and Wildlife Service, Region 3

Indianapolis, Indiana
June 2002

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
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Limitations on Use of the Ground-Water-Quality Dataset

Water-quality data obtained from GRITS/STAT and paper reports are recorded in the attached appendices on compact disc as originally reported from those sources. Some of the GRITS/STAT analyses, approximately 17 percent, had a blank in the "units" field and are reported as such. No attempts have been made to check or validate these data.

As previously noted, all concentrations are recorded as raw numbers to five decimal places. No inferences regarding analytical precision should, therefore, be made from the number of significant digits for any given concentration.

The dataset consists only of water samples with detections of the contaminants of concern. All analytical results for contaminants of concern that were reported as less than a reporting limit were considered nondetections, and were not included in the dataset. Only the wells with a sample with a contaminant detection were plotted in the figures for this report. Although present in the study area, wells from which water samples were obtained and a contaminant was not detected are not plotted on any figures in this report. Because the dataset represents only detections, the computation of distribution-based statistics from these data can be inappropriate or at least must be qualified as representing only detected concentrations. Caution must be exercised if quantitative statistical methods are applied to interpret the data.

SURFACE-WATER AND GROUND-WATER HYDROLOGY

The following section provides an overview of the surface-water and ground-water hydrology for the study area. This topic has been the subject of numerous studies, and in many instances the reader will be referred to the appropriate published material for additional detail.

Surface-Water Hydrology

Surface drainage in the study area generally is to the GCR, the IHC, and Lake Michigan in the north and to the LCR in the south. The drainage divide separating these areas of surface-water dischage approximately coincides with the Tolleston Beach Ridge, an arcuate upland in the southern part of the study area (fig. 2).

Surface-water flow in the NRDA portion of the study area has been altered greatly by human activity. Before about the early 1800's, the Little Calumet and Grand Calumet Rivers were sections of the same stream (Crawford and Wangsness, 1987, p. 6). The ancestral Calumet River originated to the south of the study area and flowed westward through the current LCR valley into Illinois. The channel made a hairpin turn in Illinois and flowed eastward back into Indiana through the current GCR valley and discharged into Lake Michigan near the Marquette Park Lagoons (fig. 1) (Shedlock and others, 1994, p. 16; Crawford and Wangsness, 1987, p. 6).

The development of portages, ditches, and canals connecting to Lake Michigan in northeastern Illinois through the 1800's slowed and eventually reversed the eastward flow in the ancestral Calumet River. The ancestral river mouth in Indiana eventually was closed by littoral drift of sand along the shoreline (Shedlock and others, 1994, p. 16). The opening of the IHC in 1909 divided the GCR into the east branch of the Grand Calumet River (EB-GCR) and the west branch of the Grand Calumet River (WB-GCR) (fig. 1). Additional details regarding pre-development drainage in the study area can be found in Cook and Jackson (1978) and Crawford and Wangsness (1987).

The GCR in the study area now consists of the two east-west oriented branches, the EB-GCR and the WB-GCR, that meet at the southern end of the IHC (fig. 1). The Marquette Park Lagoons are the headwaters for the EB-GCR—water from these lagoons flows westward through an underground culvert that discharges to the upstream end of the main channel at the eastern end of the U.S. Steel—Gary Works property (plate 1). Water in the main channel then flows westward approximately 10 mi to its confluence with the IHC. The EB-GCR ranges in depth from 3-4 ft in the upstream reaches and about 8-10 ft at the downstream end, and has an average velocity of approximately 1 ft/s (Crawford and Wangsness, 1987, p.3).

The WB-GCR is about 6 mi long and has a depth of about 2 ft. Stream velocity in the WB-GCR ranges from 0.2 to 1 ft/s (Crawford and Wangsness, 1987, p. 3). The WB-CGR has a surface-water divide that typically is near where I-90 (the Indiana Toll Road) crosses over the WB-GCR (fig. 1). Water in the WB-GCR flows eastward from this divide towards its confluence with the IHC and westward from this divide towards its confluence with the Little Calumet River in Illinois. The position of the divide is variable and influenced by numerous factors including water levels in Lake Michigan, the amount of effluent flow into the two branches of the GCR and the IHC, and the speed and direction of the wind (Crawford and Wangsness, 1987, p. 3).

In 1986, when record-high water levels in Lake Michigan were greater than 582 ft above sea level, Fenelon and Watson (1993) and Greeman (1995) reported that the drainage divide in the WB-GCR was absent. During this time, Lake Michigan drained southward through the IHC and then, along with flow from the EB-GCR, westward through the WB-GCR into Illinois (Greeman, 1995, p. 27). Historical water-level data for the period 1917 to 2000 (U.S. Army Corps of Engineers, 2002) indicate that average monthly water levels for Lake Michigan equaled or exceeded 582 ft above sea level only during June and July 1973, July 1974, and June through November 1986.

The main channel of the IHC extends northward approximately 3 mi from its confluence with the east and west branches of the GCR and then turns northeast for an additional 3 mi to its mouth at the Indiana Harbor and Lake Michigan. The east-west oriented Lake George Branch, approximately 2 mi in length, enters the IHC at the point where the main channel bends from heading north to heading northeast (fig. 1).

The drainage area for the IHC, which includes areas draining to the Lake George Branch, the EB-GCR, and the WB-GCR east of the flow divide, is less than 45 mi^2—it cannot be determined exactly because of the shifting location of the flow divide in the WB-GCR. The sandy texture of the soils in the area generally results in small contributions to streamflow from surface runoff.

Three USGS streamflow-gaging stations are located on the GCR/IHC in the study area. The mean annual discharge for the IHC at East Chicago (station number 04092750 in fig. 1) was 647 ft^3/s for the period of record 1994-99 (Stewart and others, 2000, p. 186). Backwater from Lake Michigan affects streamflow in the IHC and to a progressively lesser extent upstream into the EB-GCR and WB-GCR. Instantaneous measurements of streamflow indicate flow reversals for periods of minutes because of localized flow from Lake Michigan into the IHC (Renn, 2000, p. 8-9).

The EB-GCR at Industrial Highway gaging station (station number 04092677 in fig. 1) had a mean annual discharge of 484 ft^3/s for water years 1995-99 (Stewart and others, 2000, p. 185). The WB-GCR at the Hohman Avenue at Hammond gaging station (station number 05536357 in fig. 1) had a mean annual discharge of 44.9 ft^3/s for water years 1991-99 with occasional flow reversals (Stewart and others, 2000, p. 234).

Discharge of ground water to the GCR contributes less than 10 percent of the total streamflow (Crawford and Wangsness, 1987, p. 123). Discharge of industrial process water and discharge from municipal wastewater-treatment plants compose more than 90 percent of the streamflow in the EB-GCR and WB-GCR (Crawford and Wangsness, 1987, p. 123). Surface water generally flows from the EB-GCR and the WB-GCR (east of the flow divide) into the IHC and discharges to the Indiana Harbor and Lake Michigan.

Ground-Water Hydrology

The study area is underlain by approximately 40 ft to more than 225 ft of unconsolidated glacial, eolian, lacustrine, and paludal sediments of Pleistocene and Holocene age. These sediments were deposited on a bedrock surface modified by pre-Pleistocene erosion. This section describes the surficial aquifer, an underlying confining unit in the unconsolidated sediments, and a bedrock aquifer below the confining unit. The section also describes ground-water-flow directions and sources of recharge to and areas of discharge from ground water.

Calumet Aquifer

Surficial sands in the study area are known as the Lake Michigan sequence from the Quaternary Period (Brown and Thompson, 1995, plate 1). These eolian and lacustrine sands, along with localized made or modified land, form a surficial aquifer in the study area commonly referred to as the Calumet aquifer.

Substantial areas of the uppermost parts of the Calumet aquifer, primarily within the NRDA portion of the study area, are made or modified land composed of fill deposits. Thousands of acres of made land cover the original lake-bed sands along the Lake Michigan shoreline (fig. 2; Indiana Department of Natural Resources, 1979) with from 10 to 40 ft of slag, and more than 80 ft of slag in limited areas (Kay and others, 1997). Materials such as steel mill slag and coal ash and to a lesser extent municipal wastes, industrial wastes (excluding slag), construction debris, dredging spoil, ash and cinders, and biological sludges have been used to cover and fill low swampy land (Kay and others, 1997, p. 24 and plate 2). A large part of the NRDA area has been used for the disposal of an estimated 5×10^9 ft^3 of principally steel and blast furnace slag. This estimate is based on areas previously mapped as containing steel-industry waste (Kay and others, 1997, plate 2), and multiplied by the average thickness of fill mapped in that area (Kay and others, 1997, plate 1).

The Calumet aquifer is unconfined throughout its extent with the exception of small areas where discontinuous layers of peat, muck, and organic deposits confine the sands (Duwelius and others, 1996, p. 5). The thickness of the Calumet aquifer (fig. 5) generally increases from west to east in the study area, and ranges from 0 ft in the extreme southwestern part of the study area to more than 100 ft in the northeast (Kay and others, 1996, p. 22). Well-driller records on file with the IDNR show approximately 55 wells open to the Calumet aquifer were drilled since 1959 for commercial, industrial, and domestic water supplies. It is likely that many of these wells still may be in use. However, the Calumet aquifer generally is not used for municipal or industrial water supply because most major users obtain their water supplies either directly from Lake Michigan or from the underlying bedrock aquifer.

Confining Unit

Throughout the study area, two unconsolidated units, the Quaternary Lake Border and Wheeler Till sequences (Brown and Thompson, 1995, plate 2), combine to form a confining unit between the underlying bedrock and the Calumet aquifer. These clay-rich unconsolidated units are glacially derived, composed primarily of eroded Mississippian-Devonian shale bedrock, and may contain thin discontinuous sand deposits (Kay and others, 1996, p. 24). The thickness of the confining unit (fig. 6) generally varies from slightly less than 50 ft to more than 150 ft.

Bedrock Aquifer

A carbonate bedrock aquifer (the "bedrock aquifer") is at the bedrock surface throughout the study area (fig. 7). This aquifer is composed of Devonian and Silurian carbonates, with a combined thickness of about 400 ft in the study area. The subcrop of the bedrock has about 75 ft of relief, and ranges in elevation from slightly less than 425 ft above sea level to slightly more than 500 ft above sea level within the study area. The most prominent feature of the bedrock surface is a north-trending valley just to the east of the IHC.

Generally, production wells only penetrate the upper 100 ft of the bedrock aquifer, as most supply needs are available within this interval (Fenelon, 1994, p. 23). Preglacial dissolution of the carbonate has increased permeability in the upper 100 ft of the bedrock aquifer. Whereas land-surface features indicative of karst topography have not been mapped on the buried bedrock surface, well drillers have reported cavern openings within the upper 100 ft of bedrock.

Ground-Water Hydraulic Properties

Hydraulic conductivity, in general terms, is a measure of the capacity for a porous medium to transmit water—the higher the hydraulic conductivity, the more readily water will move through the medium. The hydraulic gradient, in general terms, is a measure of the force pushing water in a given direction—a higher hydraulic gradient will result in more water moving in the direction of the gradient. These hydraulic properties along with the porosity, a measure of the open pore space in a medium, can be used to calculate a ground-water velocity. Following is a brief summary of findings from previous studies regarding these hydraulic properties in the study area.

Effects of Sewers

A substantial amount of ground water infiltrates into the sanitary sewers that underlie much of the study area (fig. 12) (Fenelon and Watson, 1993, p. 16). It is likely that most of this ground water, after being processed at a wastewater-treatment plant, eventually is discharged to the GCR, the IHC, or Lake Michigan. Fenelon and Watson (1993, p. 38) report the combined estimates of ground-water sewer infiltration from sanitary districts that include the cities of Gary, Hammond, Whiting, and East Chicago ranged from 15 to 50 ft^3/s. They attribute this wide variability to the difficulty in estimating and measuring domestic and industrial discharges to sewers, and total amounts of water being received at wastewater-treatment plants. Ground-water discharge to sewers is variable and is highly dependent on seasonal ground-water levels. More water infiltrates to sewers when ground-water levels are high than when ground-water levels are low, thereby complicating estimates of ground-water infiltration. A finite-difference model analysis performed by Fenelon and Watson (1993) indicates that the amount of ground-water discharge to sewers is most likely in excess of the amount of recharge from precipitation in the sewered areas.

Leakage to sewers tends to minimize ground-water-level fluctuations and contributes to stabilizing the ground-water-flow regime in affected areas. If the sewers are situated below the water table, they generally will continually receive ground water from the aquifer; this inflow to the sewer will persist until the water level in the aquifer falls to approximately the same elevation as the leaky sewer line. If they are situated above the water table, they generally will lose water to the aquifer; this loss to the aquifer will persist until the water level in the aquifer rises to approximately the same elevation as the leaky sewer line.

Effects of Pumping

Pumping from the Calumet aquifer to dewater specific sites is common in the study area. Construction companies often use pumping to dewater areas of earth-moving activities and underground construction sites, and pumping is used to maintain water levels below the bottom of sand- and gravel-mining excavations. Numerous manifold-type dewatering systems are in place to restrict contaminant movement across property boundaries and/or to recover soluble and insoluble contaminants from the aquifer (Greeman, 1995, p. 29).

Pumping lowers ground-water levels and creates a depression in the water table surrounding the pumpage. Ground-water gradients along most of the GCR/IHC usually are toward the river and canal (Fenelon and Watson, 1993, p. 25). If a depression in the water table because of pumpage extends outward from the pumping location to the GCR/IHC, a flow reversal can result and surface water can flow from the canal/river into the aquifer towards the pumping center. Periodic water-level data collected between 1986 and 1992 by Greeman (1995) indicated one occurrence of this nature that is discussed in greater detail in the section "Directions of ground-water flow".

Effects of Wetlands

Wetlands in the study area may be important in decreasing ground-water gradients and the development and duration of transient reversals along parts of the GCR/IHC. Wetlands in the study area (fig. 3) are, with a few exceptions, less than 50 acres and are situated mostly along or near streams, lakes, ponds, and ditches. Wetlands typically are among the more densely vegetated areas in the highly urbanized and industrialized GCR/IHC watershed. Ground-water gradients near the stream bank tend to flatten out, and even occasionally reverse, during periods of seasonally low ground-water levels that typically accompany the summer growing season (figs. 9-11). Fenelon and Watson (1993, p. 29) report that transient gradient reversals along stream banks lasted relatively longer in areas that were vegetated (site 1 in figs. 9-11) than in areas with little or no vegetation (site 2 in figs. 9-11).

R.E. Martin

HYDROGEOLOGIC ATLAS OF AQUIFERS IN INDIANA

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 92-4142

Prepared in cooperation with the
INDIANA DEPARTMENT of NATURAL RESOURCES, DIVISION of WATER
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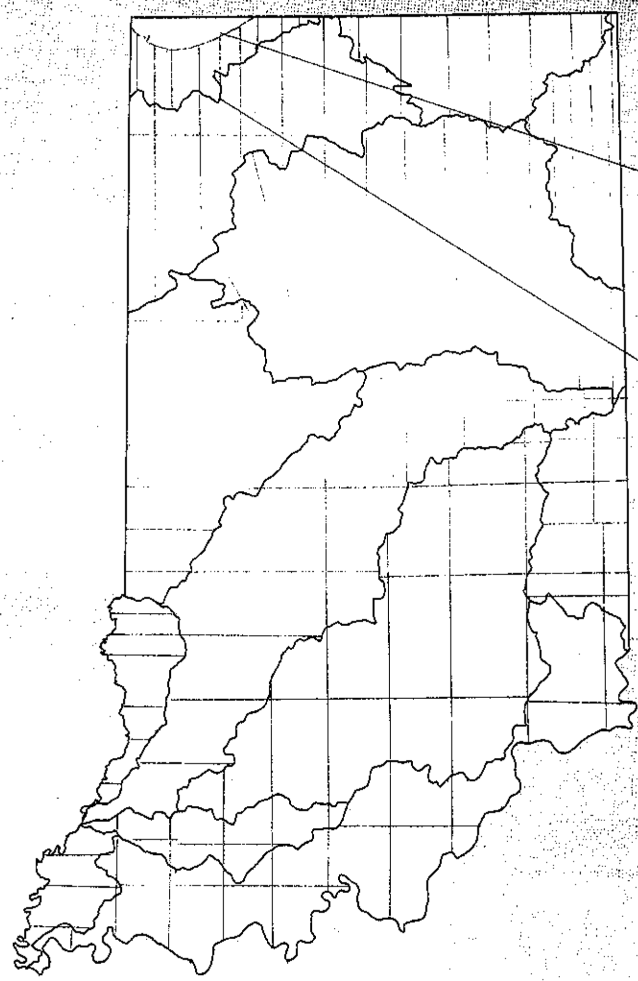
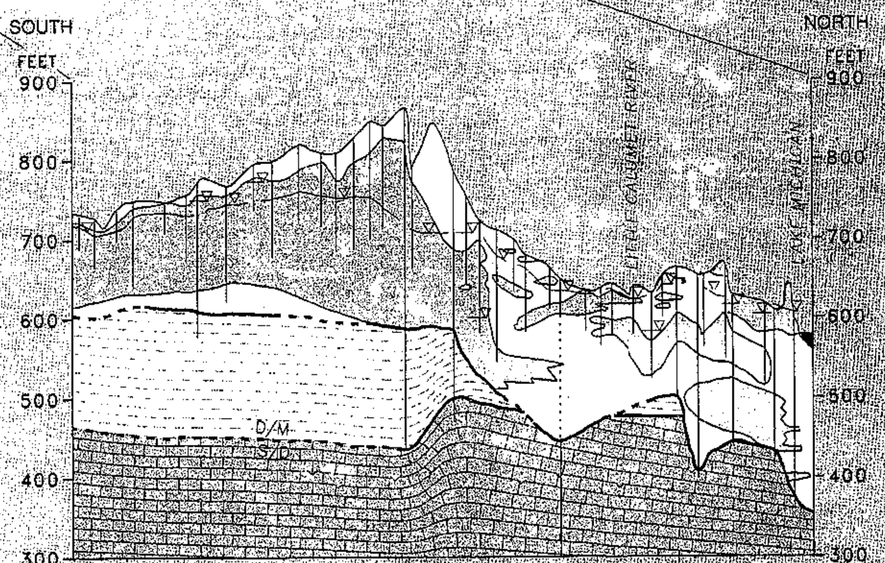




Physiography

The Lake Michigan basin lies within the Calumet Lacustrine Plain, Valparaiso Morainal Area, and Kankakee Outwash and Lacustrine Plain, which are part of the Northern Moraine and Lake Region. The Kankakee Outwash and Lacustrine Plain, located in the extreme southeastern part of the basin, is discussed in the section on the Kankakee River basin in this report. The Calumet Lacustrine Plain (fig. 13), in the northern part of the Lake Michigan basin, occupies the lake bottom of the former glacial Lake Chicago—an extension of Lake Michigan in late Wisconsinan time (Bretz, 1955, p. 108). The lacustrine plain is not a completely flat area, but is a series of beach ridges, dunes, and interridge marshes. There are three dominant relict shorelines: the Glenwood, Calumet, and Toleston beach complexes, whose elevations are approximately 625, 607, and 600 ft above sea level, respectively (Thompson, 1987, p. 46-64). Relief in the Calumet Lacustrine Plain ranges from elevations greater than 650 ft above sea level in dunal areas associated with ancient beaches to approximately 580 ft above sea level on the present day Lake Michigan shoreline.

South of the Calumet Lacustrine Plain is the Valparaiso Morainal Area (fig. 13), composed of an arc-shaped end moraine complex that parallels the southern shore of Lake Michigan from Illinois, through northwestern Indiana, and into Michigan. The morainal complex is made up of several terminal moraines of Wisconsinan age including the Valparaiso and Tinley Moraines (fig. 13), which mark terminal positions of the Lake Michigan Lobe (Bretz, 1955, p. 106-108). The Valparaiso Morainal complex is about 150 ft higher than the Calumet Lacustrine Plain and forms a major divide that separates drainage to the Mississippi River from drainage to the Saint Lawrence River by way of Lake Michigan. Elevations in the complex generally range from 700 to 800 ft above sea level and are as high as 950 ft above sea level. The western end of the complex is wide and gently undulating, whereas the part of the complex east of Valparaiso, is more hilly and rugged (Schneider, 1966, p. 51-52).

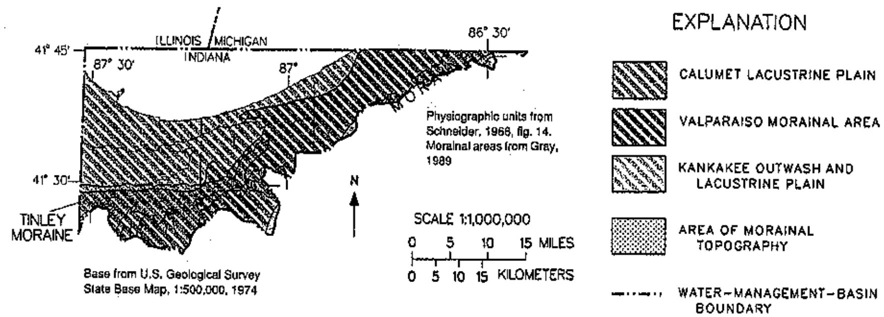


Figure 13. Physiographic units and moraines in the Lake Michigan basin.

Surface-Water Hydrology

The entire drainage area for Lake Michigan is approximately 67,900 mi^2 and includes 44,330 mi^2 of land in Indiana, Illinois, Wisconsin, and Michigan (Great Lakes Basin Commission, 1975, p. 21). Within Indiana, the Lake Michigan basin has an area of 845 mi^2, of which 604 mi^2 is land. The basin is drained in Indiana primarily by the Little Calumet River (fig. 12), which flows approximately parallel to the Lake Michigan shoreline and discharges to Lake Michigan through a ditch on the western side of Porter County. The major tributaries to the Little Calumet River are Turkey Creek, Deep River, and Salt Creek. Each tributary originates on the Valparaiso Moraine and flows north to the Little Calumet River. The eastern part of the Lake Michigan basin in LaPorte County is drained by smaller creeks that flow directly into Lake Michigan.

Geology

Bedrock Deposits

Overlying Precambrian bedrock in the Lake Michigan basin is more than 4,000 ft of sedimentary bedrock (Rosenshein and Hunn, 1968a, p. 7; Hartke and others, 1975, p. 4) that dips northeast at about 10 to 20 ft/mi. About 3,500 ft of the sedimentary bedrock is of Cambrian or Ordovician age. The Cambrian and Ordovician bedrock consists of about 2,000 ft of fine- to coarse-grained sandstone in the lower part and shale overlying dolomite and sandstone in the upper part (Rosenshein and Hunn, 1968a, p. 9; Hartke and others, 1975, p. 4). Overlying these rocks are Silurian rocks in the western part of the Lake Michigan basin and Silurian, Devonian, and Mississippian rocks further east (figs. 5 and 14).

The rocks of Silurian age, which consist of 400 to 600 ft of dolomite and some limestone (Great Lakes Basin Commission, 1975, p. 37), are divided into the Sexton Creek Limestone, the Salamonie Dolomite, and the Salina Group (Shaver and others, 1986). The Silurian rocks are composed of shaley to pure and fine- to coarse-grained carbonate rocks that include reef facies in the upper part.

The Devonian rocks consist of dolomite and limestone overlain by shale; these rocks contain the Muscatatuck Group and the Antrim and Ellsworth Shales. The Muscatatuck Group overlies the Silurian carbonate rocks; it is absent where Silurian rocks are exposed at the bedrock surface, and it is as much as 200 ft thick elsewhere (Shaver, 1974, p. 5). The Group is composed of a wide variety of impure to pure and dense to coarse-grained dolomite and limestone; in places, it contains anhydrite and gypsum in its lower part (Shaver and others, 1986, p. 99). The Antrim Shale, a brownish-black noncalcareous shale, overlies the Devonian carbonate rocks in the northeastern part of the basin (Shaver and others, 1986, p. 5). The Ellsworth Shale overlies the Antrim Shale and is of Devonian and Mississippian age. It is a grayish-green shale that contains limestone or dolomite lenses in its upper part (Shaver and others, 1986, p. 42).

The bedrock surface is a preglacial erosional feature that has been further modified by glacial erosion. The Silurian and Devonian carbonate rocks exposed at the bedrock surface contain significant fractures and solution features in the upper 100 ft (Rosenshein and Hunn, 1968a, p. 10; Great Lakes Basin Commission, 1975, p. 24; Hartke and others, 1975, p. 4).

Unconsolidated Deposits

The unconsolidated deposits in the Lake Michigan basin are largely the result of glacial, glaciofluvial, shallow-water coastal and lake, wetland, and wind-blown sedimentation. They consist of clay-rich till, sand and gravel outwash, sand beaches and dunes, lake silt and clay, and peat. Thicknesses of unconsolidated deposits range from about 50 ft near the Indiana-Illinois State line to about 350 ft at the basin divide south of Michigan City (fig. 15). The Lake Michigan basin is overlain in most areas by two or more of four general unconsolidated units (Rosenshein, 1962b; Vig, 1962; Hunn and Reussow, 1968; Rosenshein and Hunn, 1968a, 1968b; Hartke and others, 1975).

The lowest unit overlies bedrock and is primarily a dense, clay-loam till that contains zones of intertill sand and gravel. This unit, which ranges in thickness from 0 to more than 100 ft, was formed by Wisconsinan and possibly pre-Wisconsinan glaciers that advanced through the basin. The basal part of the unit contains 0 to 15 ft of sand and gravel that fill the deepest parts of preglacial bedrock valleys.

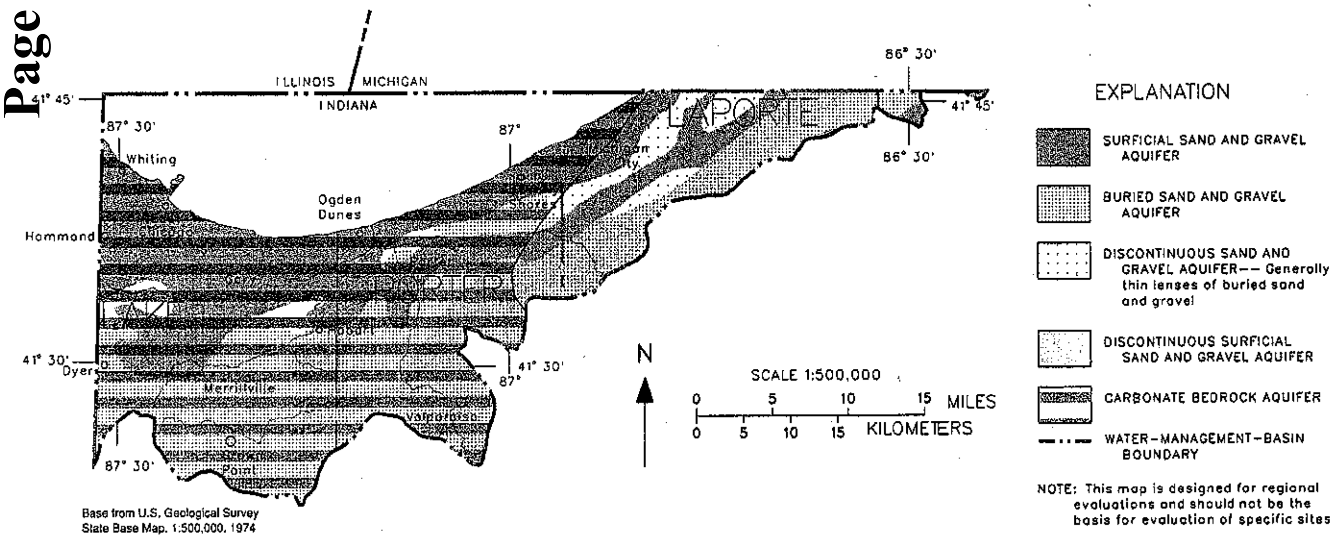


Figure 17. Extent of aquifer types in the Lake Michigan basin.

Unconsolidated Aquifers

Buried Sand and Gravel Aquifers

Buried sand and gravel aquifers are found in more than three-fourths of the basin (fig. 17). Most of the buried aquifers are part of a glaciofluvial sand aquifer, which is shown on the southern one-half to two-thirds of sections 1A–1A′ to 1F–1F′ (fig. 16). The aquifer as shown in the sections consists of sand bodies that are continuous for 3 to 6 mi in a north-south direction. These sand bodies are probably more continuous parallel to Lake Michigan and the Valparaiso Moraine. The buried glaciofluvial aquifer is as much as 200 ft thick (of which 150 ft is saturated) beneath the Valparaiso Moraine in section 1E–1E′ (fig. 16). The typical thickness penetrated by wells is about 50 ft; however, aquifer thicknesses may be greater because most of the wells do not penetrate the full thickness of the aquifer.

The glaciofluvial sand aquifer is overlain by a surficial till in most areas on the Valparaiso Morainal complex. Till thickness ranges from 0 to about 100 ft and is typically 20 to 50 ft. The aquifer is recharged primarily from the overlying till. The aquifer discharges to the land surface through the overlying till and to the bedrock through a basal till (Rosenshein and Hunn, 1968b). In sections 1F–1F′ and 1G–1G′ (fig. 16), north of the Valparaiso Moraine, hydraulic heads in the buried sand and gravel are above land surface; flowing wells can be found in these areas.

Several localized buried aquifers are between sections 1D–1D′ and 1F–1F′ in the northern part of the basin. These aquifers have been studied by a number of investigators (Wilcox and others, 1986; Shedlock and others, 1987; Shedlock, Wilcox, Thompson, and Cohen, 1993; Shedlock, Cohen, Imbrigiotta, and Thompson, in press) and have been named the "subtill" and "basal" aquifers. The "subtill" aquifer, shown on section 1E–1E′ in T. 37 N. (fig. 16), is buried beneath a surficial till and overlies another till. The aquifer extends almost 5 mi and is about 30 ft thick in section 1E–1E′. Beneath the underlying till in places is the "basal" aquifer, which extends about 2 mi in section 1E–1E′ and is about 50 ft thick.

Unmapped intertill sands and gravels in the basal and surficial tills in the southern one-half of the basin also contribute water to wells locally. Yields of some of these aquifers are high, but the aquifers are not extensive (Rosenshein and Hunn, 1968a; 1968b).

Surficial Sand and Gravel Aquifer

The unconsolidated surficial aquifer in the northern one-half of the basin is composed of glaciolacustrine and wind-blown sand. The aquifer extends south about 2 to 5 mi from the Lake Michigan shoreline in the eastern part of the basin and up to 10 mi from the shoreline in the western part of the basin. Thicknesses range from 0 to 70 ft and average about 30 ft. The surficial aquifer is recharged primarily from precipitation and from ground water flowing up from the basal till in the eastern part of the basin. Most discharge goes to streams, ditches, Lake Michigan, and to evapotranspiration (Rosenshein and Hunn, 1968b; Shedlock and others, 1987; Fenelon and Watson, 1993). The aquifer is used very little as a source of water in the western part of the basin because of its proximity to Lake Michigan, the major source of drinking water in the area. The aquifer is also rarely used because of its thin saturated zone (20 to 30 ft) and its susceptibility to contamination (Hartke and others, 1975, p. 25; Fenelon and Watson, 1993). The aquifer is tapped in the eastern part of the basin by households that do not have access to a public water supply or a better source of ground water.

The surficial aquifer extends for an undetermined distance beneath Lake Michigan. Sand or gravel has been found on the lake bottom at widely spaced sampling points within the State boundaries (Schneider and Keller, 1970). The distribution of sand and gravel indicates that the aquifer could extend more than 5 mi into the Lake, although insufficient data are available to map the areal extent or thickness.

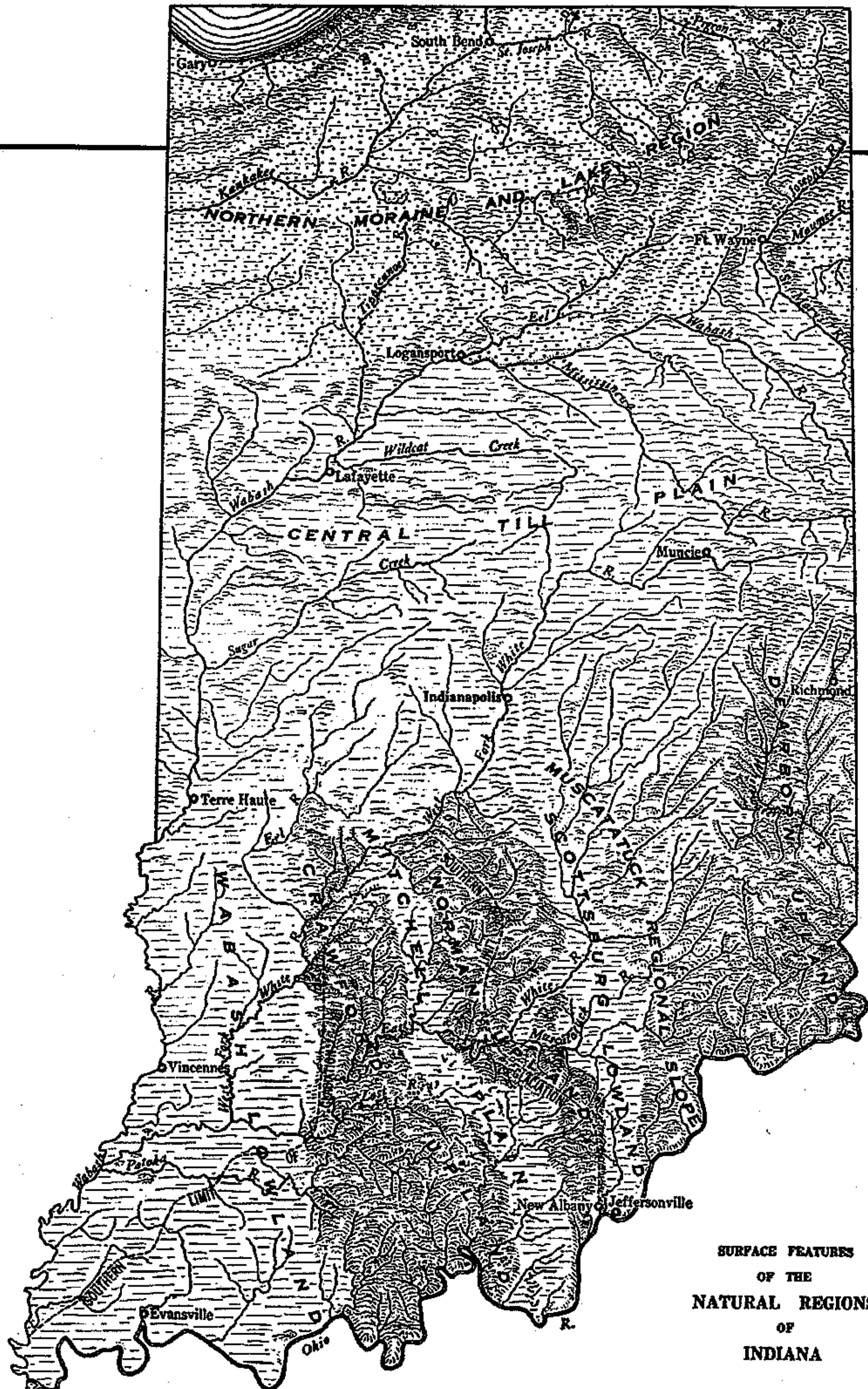
Discontinuous Sand and Gravel Aquifers

Discontinuous buried sand and gravel aquifers are present in the northeastern part of the basin and are shown in the central part of section 1G–1G′ (fig. 16). Although the deposits are discontinuous, they are common enough that sources of domestic water supply are easy to find. Some of the discontinuous aquifers are in the deep bedrock valleys in the northeastern part of the basin. Section 1G–1G′ (fig. 16) crosses several of the valleys that are 200 to 300 ft below land surface and have about 100 ft of relief. The bottom of one of the valleys is filled with sand and gravel, which is tapped for a drinking-water supply; however, in general, these deep aquifers are not tapped unless they are the only unconsolidated aquifers in the area.

PHYSIOGRAPHIC DIVISIONS OF INDIANA

Special Report 61

R.E. Martin



SURFACE FEATURES
OF THE
NATURAL REGIONS
OF
INDIANA

INDIANA UNIVERSITY
INDIANA GEOLOGICAL SURVEY

PHYSIOGRAPHIC DIVISIONS OF INDIANA

By Henry H. Gray

INTRODUCTION

It has now been more than 70 years since C. A. Malott (1922) definitively outlined the physiographic regions of Indiana. Earlier observations, for example, by Newsom (1898), Dryer (1912), Leverett and Taylor (1915), and Fenneman (1917), along with earlier work by Malott himself, were incorporated into his treatise. Relatively minor revisions have since been suggested by Wayne (1956) and Schneider (1966).

Since Malott's time, complete topographic coverage of Indiana at 1:24,000 scale has become available and advances have been made in knowledge and understanding of Indiana geology, particularly of the glacial geology of the northern two-thirds of the state. Aerial photographs at several scales are available for the entire state, and the soils in every county have been mapped in detail. It is not possible to cite all these resources, but they make it appropriate to revise and refine Malott's concepts of the physiographic regions of Indiana. I do not, however, offer as exhaustive a discussion as did Malott.

The physiographic sections defined and described below are grouped into four regions (Plate 1). The northernmost region is essentially the Northern Moraine and Lake Region of Malott (1922), somewhat differently subdivided. The topography of this region is almost entirely the result of glacial action, and because the drift is thick, no exposures of bedrock are known in the entire region. A small part of the Maumee Lake Plain Region, which is extensive in northwestern Ohio, reaches into northeastern Indiana. The Central Till Plain Region, essentially the Tipton Till Plain of Malott, is for the first time subdivided into several sections. Here also glacial influence is dominant, but the drift is thinner and in many places, especially along streams, bedrock appears at or very near the surface. In the definition and classification of these three regions I have been guided in many details by the work of Fleming and others (1994).

The Southern Hills and Lowlands Region, that part of the state that has not been profoundly affected by the latest (Wisconsin) glaciation and in which bedrock is at or near the surface in much of the region, is subdivided into sections that for the most part are refinements of Malott's regions. All names for the sections, including those newly defined here, were chosen from prominent geographic features—towns, counties, lakes, or rivers.

Homoya and others (1985) have defined Natural Regions of Indiana that are in some places more or less congruent with the physiographic sections herein described. The Natural Regions are defined by biological assemblages and are influenced, therefore, by other underlying factors as well as topography—climate, soils, and drainage, for example—and so the coincidence is not complete. Comparison of Homoya's map (1985, pl. 1) with the map presented here (Plate 1) provides the best way to evaluate the correspondences, but in the text that follows, reference is made in those places where the physiographic and natural regions are most similar.

1. NORTHERN MORAINE AND LAKE REGION

This region is nearly coincident with Malott's (1922) Northern Moraine and Lake Region, and although it includes tracts of lake plain and large areas of outwash, it is dominantly morainic and contains within its borders almost all of Indiana's natural lakes. It is appropriate, therefore, to retain Malott's name. The topography of this region has been created almost entirely by depositional and erosional action of the latest, or Wisconsin, glaciation. The physiographic sections described below differ from the sections described by Malott, mainly through better understanding of the three glacial lobes that built the present topography.

Even at its maximum extent—which was not all accomplished at exactly the same time—ice of the Wisconsin glacier exhibited distinct flow-patterns (fig. 1). One result of this is the different composition of tills associated with the separate ice streams; another is the character and lineation of the physiographic features left behind. These show that deposits of the Huron–Erie Lobe, which entered the state from the east along the axis of the upper Wabash Valley, are by far the most extensive, spreading to the Wisconsin glacial boundary in central and southeastern Indiana and to the Illinois state line near Kentland, where they overlap deposits of the Lake Michigan Lobe. Deposits of the Lake Michigan Lobe extend to the Wisconsin glacial boundary in west-central Indiana and are at the surface only in areas of lesser size, but they also are widely present beneath the overriding blanket of Huron–Erie Lobe deposits.

By about 15,000 years ago, the ice margin had retreated to northern Indiana and each of the ice streams developed a lobate margin and a distinctive behavior pattern. The Erie

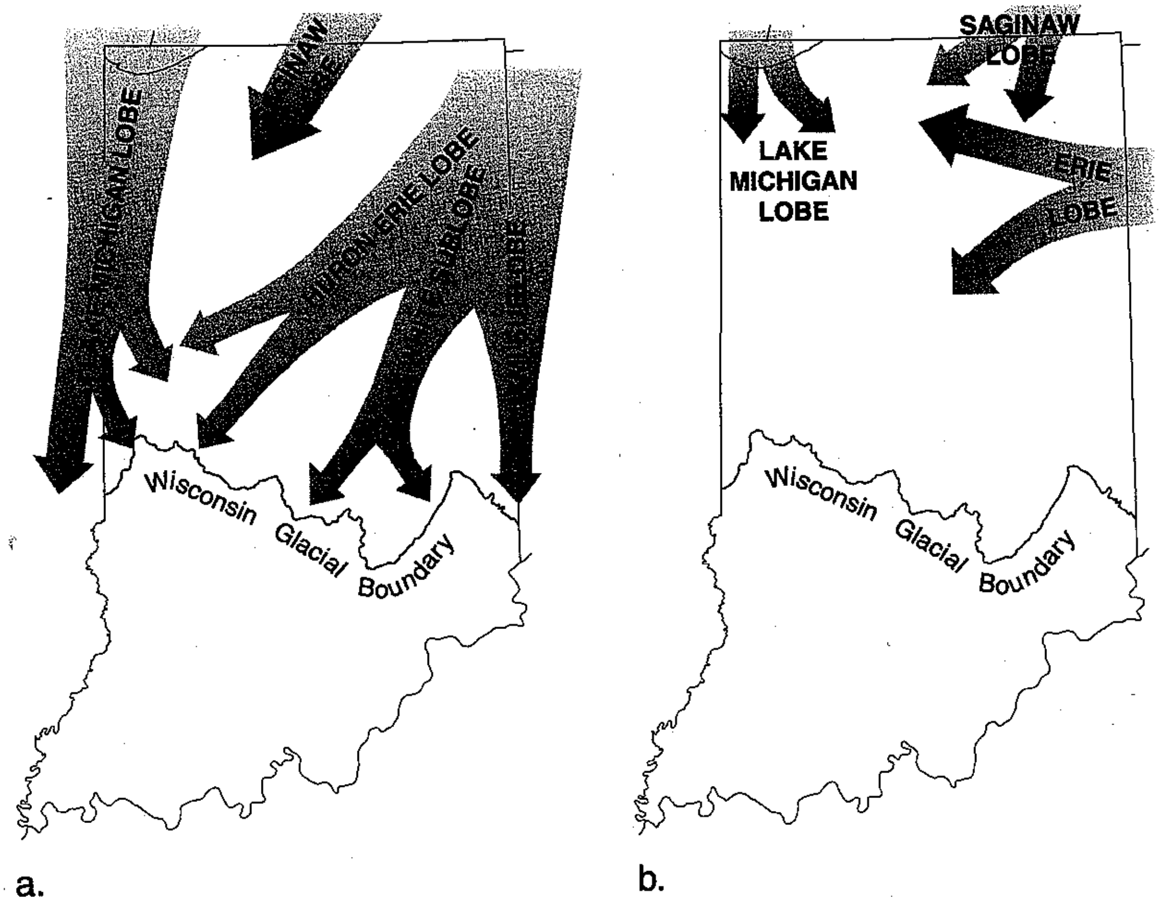


Figure 1. Sketch maps showing generalized flow direction of the several ice streams that made up the Wisconsin glacier in Indiana: a) about 20,000 years ago; b) about 15,000 years ago. Because of the vacillating activity of the several lobes and in some places extensive overriding of one lobe over another, it is not possible to show lobe margins in any meaningful way.

Lobe readvanced out of the basin of Lake Erie, bringing with it much clay from the floor of a temporary proglacial lake; the less active Saginaw Lobe advanced southwestward down the axis of Saginaw Bay only as far as northeasternmost Indiana, bringing a sandier load. And whereas earlier these and the Lake Michigan Lobe sparred for position across the central area of the Northern Moraine and Lake Region, leading to considerable stratigraphic and topographic complexity, the area of interaction was, during this latest phase of glaciation, much reduced.

1a. The Lake Michigan Border (Plate 1), which is essentially Malott's (1922) Calumet Lacustrine Section, is a belt 4 to 11 miles (6 to 18 kilometers) wide along the southern shore of Lake Michigan. The Valparaiso Morainal Complex (1b) adjoins the Lake Michigan Border on the south.

This section is a complex of moraines, beach ridges, lake-floor deposits and related washed surfaces, and dunes. These are among the most recently constructed major landforms in Indiana. As ice of the Lake Michigan Lobe receded from the Valparaiso Morainal Complex, beginning some 15,000 years ago, the massive moraines blocked southward drainage and a crescent-shaped lake was formed between the glacier margin and the moraine. This lake found an outlet westward, eventually down the Des Plaines and Illinois Rivers. Beach ridges mark the series of lake shores, and indistinct and discontinuous moraines record minor readvances of the ice. Continued recession of the ice allowed lake levels to fall until eventually the entire lake basin was free of ice so that drainage could exit, as it does now, by way of the Straits of Mackinac.

The most recent and relatively stable stage of Lake Michigan has built beaches and massive dunes, for example, those in Dunes State Park and at Indiana Dunes National Lakeshore. Also in parts of this section are large areas of made and modified land, especially in industrial districts and along the shore of Lake Michigan.

transmittal letter

Indiana Department of Highways
Toll Road Division
52551 ash road·post office box 1·granger, indiana 46530-0001·(219)674-8836

Oct 10 9 17 AM '89
OFFICE OF SOLID AND HAZARDOUS WASTE MGMT SEN

To: Ed Gefell
Indiana Dept. of Environmental Mgmt
105 South Meridian
Indianapolis, In. 46206

Date: October 6, 1989

Contract No.

Toll Road File

Gentlemen: We are sending the following material:

☐ herewith ☐ under separate cover ☐ by our messenger ☐ by your messenger

☐ shop drawings ☐ prints ☐ bid documents ☐ sample proposal ☐ copy of letter

☐ specifications ☐ request for payment ☐ change order ☐ tracings

☐ ☐ ☐

DATE	COPIES	DESCRIPTION
10-6-89	1	Soil borings and Geotechnical Data
		Milepost 10SR912 South Interchange

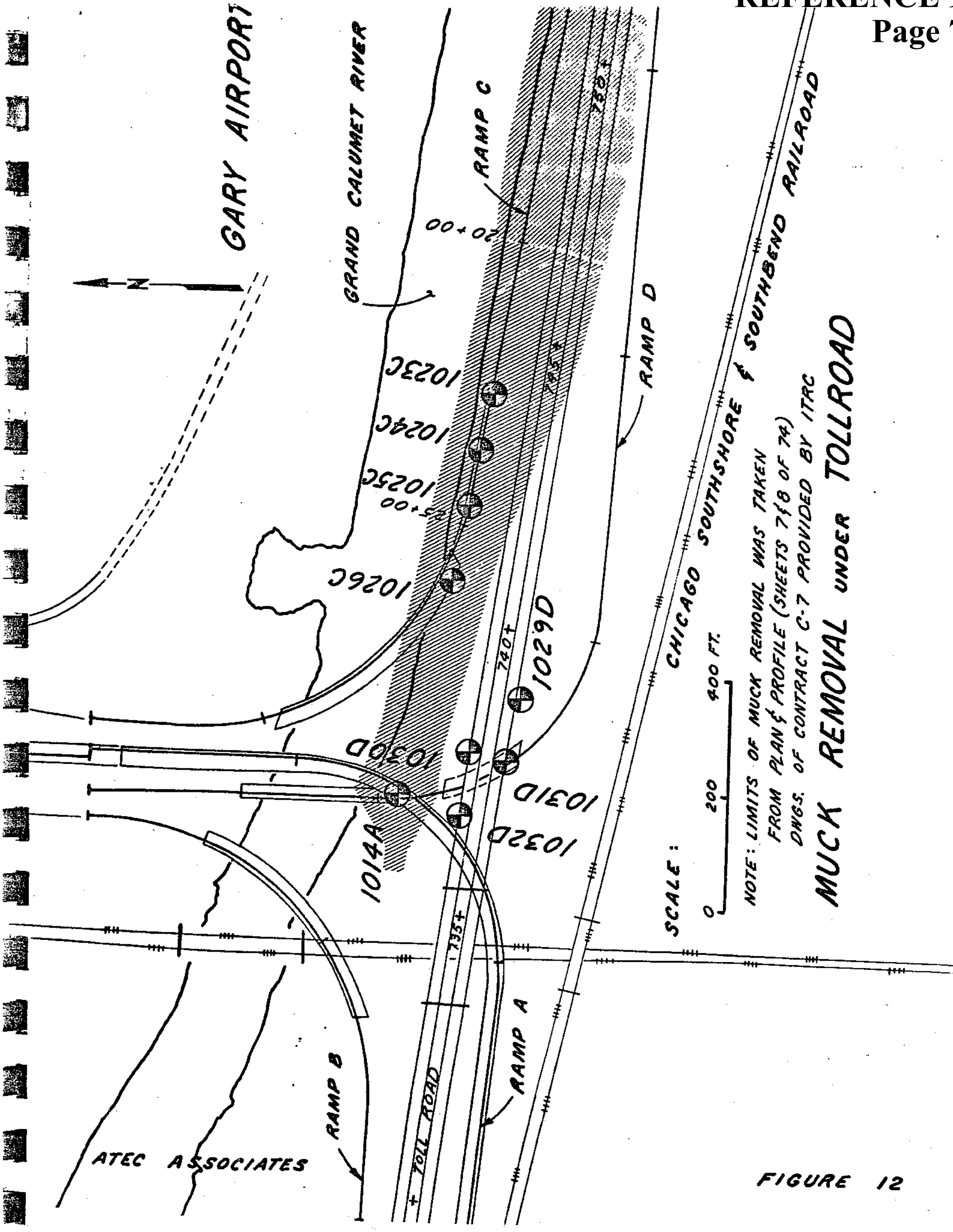
These are forwarded: ☐ for your use ☐ for correction ☐ reviewed as noted

☐ for approval ☐ for your signature ☐ for review and comment ☒ for your files

Comments:

cc:

by John R. Crist, P.E.
title Highway Engineer



NOTE: LIMITS OF MUCK REMOVAL WAS TAKEN FROM PLAN & PROFILE (SHEETS 7 & 8 OF 74) DWGS. OF CONTRACT C-7 PROVIDED BY ITRC

MUCK REMOVAL UNDER TOLLROAD

FIGURE 12

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1001A

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 717+76; 83' Rt.
FOREMAN K. Cardinal
INSPECTOR -

JOB NO. 2103189-10
DATE 3/27/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 590.5)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN; THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
TOPSOIL 0.6' Tan dry medium dense fine Sand with trace Silt (FILL)	2.5		1	3 5/6	75		**Soil classification by Textural Classification System
Tan dry to wet medium dense fine SAND (SP) with trace Silt -wet below 6.0' (SAND)**		5	2	6 12/14	100		
			3	4 6/7	100		
	12.5	10	4	6 8/9			
Gray wet dense fine SAND (SP) with trace Silt (SAND)**		15	5	10 17/22	75		Borehole caved to 4.8 ft upon completion.
Bottom of Test Boring @ 15.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 7.1 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1010A

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 733+28; 116' Rt.
FOREMAN D. White
INSPECTOR -

JOB NO. 21-03189-10
DATE 03-12-81
BORING METHOD CA/RC
ROCK CORE DIA. 2.0 IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 591.1)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
TOPSOIL	0.4						
Brown to Dark Brown slightly moist medium dense fine SAND (SP) with trace Silt (SAND)**			1	9 11/13	75		**Soil classification by Textural Classification System
	5.5	5	2	4 6/12	50		
Brown wet dense fine SAND (SP) with trace Silt (SAND)**			3	11 18/28	50		
		10	4	9 18/22	50		
	12.0						
Gray moist very dense fine SAND (SP) with trace Silt (SAND)**		15	5	18 24/31	75		
		20	6	23 36/45	75		
	22.0						
Gray wet very dense SILTY fine SAND (SM) (SANDY LOAM)**		25	7	26 44/40	100		
		30	8	16 27/34	100		
	31.5						
Gray moist medium dense fine SAND (SP) with trace Silt (SAND)**	35.5	35	9	18 18/10	100		
Gray moist stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**			10	5 6/7	100		
		40					

WATER LEVEL OBSERVATIONS
NOTED ON RODS - FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA—HOLLOW STEM AUGER
CFA—CONTINUOUS FLIGHT AUGER
DC —DRIVEN CASING
MD —MUD DRILLING
RC —ROCK CORING
CA —CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1010A

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 733+28; 116' Rt.
FOREMAN: D. White
INSPECTOR:

JOB NO. 21-03189-10
DATE 03-12-81
BORING METHOD CA/RC
ROCK CORE DIA. 2.0 IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION 591.1

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist stiff to very stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**		40					
			11	5 7/9	100		**Soil classification by Textural Classification System
		45					
			12	4 5/7	100		
		50					
			13	4 5/7	100		
		55					
			14	4 7/7	100		
	59.5						
Gray moist stiff to medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**		60					Borehole advanced using rotary drilling technique below 60.0'
			15	4 4/7	100		
		65					
			16	3 4/7	100		
		70					
			17	4 4/5	100		
		75					
			18	7 7/9	100		
	78.5						
Gray slightly moist hard SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel (CLAY)**		80					

WATER LEVEL OBSERVATIONS
NOTED ON RODS - FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1010A

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 733+28; 116' Rt.
FOREMAN D. White
INSPECTOR -

JOB NO. 21-03189-10
DATE 03-12-81
BORING METHOD CA/RC
ROCK CORE DIA. 2.0 IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 591.1)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN. THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray slightly moist hard SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel (CLAY)**		80	19	8 16/21	100		**Soil classification by Textural Classification System
	85.1		20	50/0.1	0		
Gray, slightly weathered, with a little solutioning, hard, very close to closely jointed, fine grained to crystalline dolomitic LIMESTONE with oil - tar filled cavities		85		RC Run No. 1	83		Rock Core Run #1: 85.1' to 95.1' RQD = 34%
		90					
Bottom of Test Boring @ 95.1'		95					

WATER LEVEL OBSERVATIONS
NOTED ON RODS - FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1022B

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 735+75; 460' Lt.
FOREMAN: R. Groves/K. Cardinal
INSPECTOR: -

JOB NO. 2103189-10
DATE 3/28/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION 584.2

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Brown dry very loose organic SILTY SAND (SM) (SANDY LOAM)**	3.0		1	1 1/1	10		**Soil classification by Textural Classification System
Gray wet loose fine SAND (SP) with trace Silt (SAND)**		5	2	4 5/5	80		
			3	2 3/3	70		
		10	4	3 5/4	70		
		15	5	4 4/8	40		
		20	6	5 6/12	100		
	28.5	25	7	8 10/14	100		
Wood layer	30.0	30	8	10 10/12	60		
Gray moist very stiff SILTY CLAY (CL) with trace fine to coarse Sand and Gravel		35	9	8 10/10	100		Borehole advanced using rotary drilling technique below 35.0 ft.
		40	10	8 11/14	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 3.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1022B

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 735+75; 460' Lt.
FOREMAN: R. Groves/K. Cardinal
INSPECTOR: -

JOB NO. 2103189-10
DATE 3/28/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 584.2)	STRATUM DEPTH, FT.	DEPTH, FT.	SAMPLE NO.	STD. PENETRATION BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**		45	11	4 4/5	100		**Soil classification by Textural Classification System
		50	12	3 4/4	100		
	52.0						
Gray moist very stiff SILT (ML) with a little Clay (SILT)**		55	13	13 14/13	80		
	56.0						
Gray moist stiff to very stiff SILTY CLAY (CL) with a little fine to coarse Sand and trace Gravel (CLAY)**		60	14	5 6/7	100		
		65	15	5 5/7	100		
		70	16	6 7/8	100		
		75	17	6 9/11	40		Two attempts were made to recover Sample No. 17.
	77.0						
Gray moist very stiff SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel with some very thin Silt seams (CLAY)**		80	18	8 ~~10/13~~	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 3.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1022B
Page 3 of 3

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 735+75; 460' Lt.
FOREMAN R. Groves/K. Cardinal
INSPECTOR -

JOB NO. 2103189-10
DATE 3/28/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 584.2)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN. THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist very dense SILTY CLAY (CL) with little fine Sand and fine Gravel (CLAY)**	82.0						**Soil classification by Textural Classification System
Gray slightly moist hard SILTY CLAY (CL) with some fine to coarse Sand and trace Gravel (CLAY)**	88.0	85	19	25 40/50 0.3	100		
Gray slightly moist hard SILTY SAND (SM) with little clay (SANDY LOAM)**	89.6	90	20	39 50/0.2	100		[c]Borehole caved to 4.0' upon completion.
Gray slightly moist hard SANDY SILT (ML) with little Clay (SILTY LOAM)**		95					
Bottom of Test Boring @ 93.2'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 3.5 FT.
AT COMPLETION - FT. c
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1039E

Page 1 of 3

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 733+75; 2290' Lt.
FOREMAN: R. Hackman
INSPECTOR: M. Surendra

JOB NO. 2103189-10
DATE 4/2/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 589.6)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN; THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Brown moist loose to medium dense fine SAND (SP) with trace Silt (SAND)**			1	1 3/3	100		**Soil classification by Textural Classification System
-wet below 6.0'		5	2	4 5/6	100		
			3	3 3/4	80		Introduced water below 7.5 ft to maintain a stable hole
		10	4	3 4/7	100		
	13.0						
Gray wet dense fine SAND (SP) with trace Silt and trace Shells (SAND)**		15	5	9 19/23	80		
		20	6	9 21/40	100		
		25	7	8 26/42	100		
		30	8	12 28/38	100		
		35	9	9 13/18	60		
Gray moist SILTY CLAY (CL) with trace fine Sand and trace Shells (CLAY)**	39.0	40	10	3 3/4	100		Two samples taken

WATER LEVEL OBSERVATIONS
NOTED ON RODS 7.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1039E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 733+75; 2290' Lt.
FOREMAN R. Hackman
INSPECTOR M. Surendra

JOB NO. 2103189-10
DATE 4/2/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 589.6)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist soft to medium stiff SILTY CLAY (CL) with trace fine Sand and trace Shells and trace Gravel			11	3 5/5	100		
		45	12	3 3/5	100		Borehole advanced using rotary drilling technique below 45.0'
(CLAY)**							
		50	13	2 4/4	100		
		55	14	3 5/5	100		**Soil classification by Textural Classification System
		60	15	3 4/5	100		
		65	16	2 3/3	100		
	66.0						
Gray slightly moist soft SILTY CLAY (CL) with trace fine Sand and trace Gravel			17	2 3/5	100		Sampler was sunk from 66.0 to 66.5 ft under its own weight.
-moist below 68.0'			18	3 4/5	100		
(CLAY)**		70					
-some fine to medium Sand from 74.5 to 75.0'		75	19	3 4/4	100		
		80	20	6 5/6	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 7.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA—HOLLOW STEM AUGER
CFA—CONTINUOUS FLIGHT AUGER
DC —DRIVEN CASING
MD —MUD DRILLING
RC —ROCK CORING
CA —CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ĀTEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1039E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 733+75; 2290' Lt.
FOREMAN R. Hackman
INSPECTOR M. Surendra

JOB NO. 2103189-10
DATE 4/2/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 589.6)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist meduim stiff SILTY CLAY (CL) with trace to some fine Sand and trace Gravel (CLAY)**		85	21	4 4/8	100		**Soil classification by Textural Classification System
	90.5	90	22	5 7/10	100		
Gray slightly moist hard SILTY CLAY (CL) with trace Sand and trace Gravel (CLAY)**		95	23	18 26/32	100		
		100	24	20 35/38	100		
		105	25	15 20/33	60		
		110	26	22 20/30	100		
Bottom of Test Boring @ 110.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 7.5 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA—HOLLOW STEM AUGER
CFA—CONTINUOUS FLIGHT AUGER
DC —DRIVEN CASING
MD —MUD DRILLING
RC —ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1040E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 732+50; 2380' Lt.
FOREMAN R. Hackman
INSPECTOR A. Spencer

JOB NO. 2103189-10
DATE 4/10/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION 584.6

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Dark Brown moist loose SILTY organic SAND (SM) with roots (SANDY LOAM)**	1.5		1	2 3/4	80		Two samples taken
Brownish Gray wet loose fine to medium SAND (SP) with trace Silt (SAND)**		5	2	2 2/4	100		**Soil classification by Textural Classification System
	8.0		3	3 3/5	100		
Gray wet dense to very dense SAND (SM) with little Silt -very thin wood seam at 9.5' (SANDY LOAM)**		10	4	12 16/25	100		
		15	5	15 38/50 0.4	100		
		20	6	17 28/33	100		
	27.0	25	7	15 23/28	100		
Gray wet medium dense very fine SAND (SM) with little Silt (SANDY LOAM)**	32.5	30	8	8 12/17	75		
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace small Gravel (CLAY)**		35	9	3 3/4	90		
Bottom of Test Boring @ 35.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 1.0 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.

Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1046E

CLIENT: Indiana Toll Road Commission
JOB NO. 2103189-10.
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
DATE: 4/7/81
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING METHOD: HSA
BORING LOCATION: Station 723+00; 2751' Lt.
ROCK CORE DIA. - IN.
FOREMAN: R. Hackman
SHELBY TUBE DIA. - IN.
INSPECTOR: A. Spencer

MATERIAL DESCRIPTION (SURFACE ELEVATION 586.7)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray dry very stiff ash with some slag cobbles (FILL)	2.0		1	4 50/0.2	80		**Soil classification by Textural Classification System
Tan dry medium dense fine SAND (SP) with trace Silt (SAND)**		5	2	4 5/7	100		
			3	4 9/13	100		
	12.0	10	4	5 7/8	100		
Gray wet dense to medium dense fine SAND (SP) with trace Silt (SAND)**		15	5	8 17/21	100		
562.5	24.2	20	6	3 5/12	100		
Gray wet very dense fine to coarse SAND (SP) with trace Silt and trace Gravel (SAND)**	24.8	25	7	14 29/37	100		Two samples taken.
Gray wet medium dense fine SAND (SP) with trace Silt (SAND)** -thin fine to coarse Sand seam at 29.0 to 29.2'	33.0	30	8	8 11/18	100		
Gray and Brown wet loose fine to coarse SAND (SP) with little Gravel (SAND)**	36.0	35	9	8 3/3	35		
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**			10	3 3/4	100		

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.0 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA — HOLLOW STEM AUGER
CFA — CONTINUOUS FLIGHT AUGER
DC — DRIVEN CASING
MD — MUD DRILLING
RC — ROCK CORING
CA — CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.
Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1046E

CLIENT: Indiana Toll Road Commission
PROJECT NAME: 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION: Mile Post 10; State Road 912 South Interchange
BORING LOCATION: Station 723+00; 2751' Lt.
FOREMAN: R. Hackman
INSPECTOR: A. Spencer

JOB NO. 2103189-10
DATE 4/7/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 586.7)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION SAMPLE NO.	BLOWS/6 IN; THREE 6 IN. INCREMENTS	RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand (CLAY)**	44.8		11	3 4/5	100		**Soil classification by Textural Classification System
		45	12	4 4/5	100		
Gray moist medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**	48.0						
Gray moist medium stiff SILTY CLAY (CL) with trace fine Sand (CLAY)**	52.5	50	13	3 5/5	80		
Gray moist stiff to medium stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace small Gravel (CLAY)**		55	14	4 5/7	100		
		60	15	4 4/5	100		
-two thin Silty Sand seams from 64.0 to 64.4'		65	16	4 6/6	100		
		70	17	4 4/5	100		
		75	18	4 4/5	100		
		80	19	5 5/7			

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.0 FT.
AT COMPLETION - FT.
AFTER - HRS. - FT.

BORING METHOD
HSA—HOLLOW STEM AUGER
CFA—CONTINUOUS FLIGHT AUGER
DC —DRIVEN CASING
MD —MUD DRILLING
RC —ROCK CORING
CA —CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.

Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1046E

Page 3 of 3

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 723+00; 2751' Lt.
FOREMAN R. Hackman
INSPECTOR A. Spencer

JOB NO. 2103189-10
DATE 4/7/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

SURFACE ELEVATION 586.7

MATERIAL DESCRIPTION	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN; THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
	80.5						
Gray moist stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**							
	84.0						
Gray moist stiff to very stiff SILTY CLAY (CL) with little fine to coarse Sand and trace Gravel (thin fine to coarse Sand seams from 83.5 to 84.0 ft) (CLAY)**		85	20	9 9/12	100		Two samples taken.
	87.0						
Gray moist very stiff SILTY CLAY (CL) with trace fine to coarse Sand and trace Gravel (CLAY)**		90	21	17 23/24	80		**Soil classification by Textural Classification System
	92.0						
Gray slightly moist hard CLAYEY SILT (CL-ML) with some fine to coarse Sand and trace Gravel (SILTY CLAY)**		95	22	18 22/27	100		
Gray slightly moist hard SILTY CLAY (CL) with some fine to coarse Sand and trace Gravel (CLAY)**							
Bottom of Test Boring @ 95.0'							

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.0 FT.
AT COMPLETION - FT.
AFTER - HRS - FT.

BORING METHOD
HSA—HOLLOW STEM AUGER
CFA—CONTINUOUS FLIGHT AUGER
DC —DRIVEN CASING
MD —MUD DRILLING
RC —ROCK CORING

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

ATEC Associates, Inc.

Consulting Geotechnical & Materials Engineers

LOG OF BORING NO. 1049E

CLIENT Indiana Toll Road Commission
PROJECT NAME 1980 Indiana Toll Road Improvement Project
PROJECT LOCATION Mile Post 10; State Road 912 South Interchange
BORING LOCATION Station 714+80; 2640' Lt.
FOREMAN R. Hackman
INSPECTOR A. Spencer

JOB NO. 2103189-10
DATE 4/8/81
BORING METHOD HSA
ROCK CORE DIA. - IN.
SHELBY TUBE DIA. - IN.

MATERIAL DESCRIPTION (SURFACE ELEVATION 586.1)	STRATUM DEPTH, FT.	DEPTH, FT.	STD. PENETRATION: SAMPLE NO.	STD. PENETRATION: BLOWS/6 IN; THREE 6 IN. INCREMENTS	STD. PENETRATION: RECOVERY, %	SHELBY TUBE NO.	BORING AND SAMPLING NOTES
TOPSOIL 0.1' Tan dry loose to medium dense fine SAND (SP) with trace Silt (SAND)**			1	2 2/2	100		**Soil classification by Textural Classification System
		5	2	3 4/4	100		
			3	4 7/8	100		
Gray moist to wet very dense very fine SAND (SP) with trace Silt (SAND)**	9.5	10	4	4 9/11	100		Two samples taken.
		15	5	12 20/32	100		
Bottom of Test Boring @ 20.0'		20	6	15 35/45	100		cBorehole caved to 10 ft upon completion.

WATER LEVEL OBSERVATIONS
NOTED ON RODS 11.2 FT.
AT COMPLETION - FT. c
AFTER - HRS. - FT.

BORING METHOD
HSA—HOLLOW STEM AUGER
CFA—CONTINUOUS FLIGHT AUGER
DC —DRIVEN CASING
MD —MUD DRILLING
RC —ROCK CORING
CA —CASING ADVANCER

*THESE SHELBY TUBE SAMPLES OBTAINED IN AN AUXILIARY BORING DRILLED A FEW FEET FROM THIS BORING

A Report Prepared Under Contract To:

A. T. Kearney, Inc.

Prepared for:

U. S. Environmental Protection Agency
Region V
Chicago, Illinois

INSPECTION OF GROUND-WATER MONITORING PROGRAM
GARY LAND DEVELOPMENT
GARY, INDIANA

Contract No. 68-01-6515
Work Assignment R05-005
Project 02; Task 06

HLA Job No. 6273,042.12

by

Robert C. Foster
for John M. Wilson, CPG
Senior Geohydrologist

James W. Tremblay
James W. Tremblay, P.E.
Manager, Waste Management Division

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Houston, Texas 77057
Telephone: (713) 789-8050

October 12, 1984

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APPENDICES

APPENDIX A

III ERTEC CHECKLIST

A. Summary

The following portions of the ERTEC Checklist were completed during the site inspection at GLDC:

> "Appendix A-1 Facility Inspection Form for Compliance with Interim Status Standards Covering Ground-Water Monitoring."
>
> "Appendix B - Ground-Water Monitoring and Alternate System Technical Information Form."

Since GLDC is not monitoring ground water in accordance with RCRA regulations, many of the questions contained in the Checklist are not applicable. However, an attempt was made to complete both forms as accurately as possible.

B. Deficiencies

The following deficiencies were noted during completion of the form and during the on-site well inspection:

1. Few of the documents required by RCRA have been completed. These include: the ground-water monitoring program, the ground-water sampling and analysis plan, and an outline of the ground water assessment program.
2. Many of the ground-water quality parameters required by RCRA requlations have not been established at the GLDC facility.
3. The existing geologic and hydrologic data is insufficient.

boring info - we need

4. Due to the method of construction, the monitoring wells are inadequate for RCRA ground-water monitoring. The monitoring wells were installed in a hole which was excavated by a backhoe and was then backfilled with sand around a screen. Bentonite or concrete seals were not installed; thus, the wells are subject to contamination from surface. One well (S) was completed utilizing a steel casing, which was observed to be completely rusted through at the surface. All four existing wells contain bottom sediment, but since information concerning the original well depths was not available, the efficacy of the well screens could not be determined. In the event GLDC is required to do RCRA monitoring, new wells will have to be installed and properly completed in order to meet existing regulatory standards. no seal!

5. Suitable water collection, sample preservation, and chain-of-custody and preparation procedures have not been developed or utilized.

6. Since existing ground elevations at the site were not available, conclusive information concerning the direction of ground-water flow and hydraulic gradient could not be determined at this time.

GEOLOGY OF PLEISTOCENE DEPOSITS OF LAKE COUNTY, INDIANA

By

J. S. Rosenshein

1962

Ind - 31-a

level just upstream from Rocks Village and below 77 feet between miles 16 and 17.

The geologic implications of the seismic records remain to be clarified by further mapping, seismic exploration, and test drilling. In particular, further work will be needed to relate the configuration of the bedrock surface to the history of glacial deposition in the region.

REFERENCES

Baker, J. A., Healy, H. G., and Hackett, O. M., 1961, Ground-water conditions in the Wilmington-Reading Area, Massachusetts: U.S. Geol. Survey open-file report, 162 p.

Clapp, C. H., 1921, Geology of the igneous rocks of Essex County, Massachusetts: U.S. Geol. Survey Bull. 704, 132 p.

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U.S. Geological Survey
Prof. Paper 450-D 1962

157. GEOLOGY OF PLEISTOCENE DEPOSITS OF LAKE COUNTY, INDIANA

By J. S. Rosenshein, Indianapolis, Ind.

Work done in cooperation with the Division of Water Resources, Indiana Department of Conservation

Evaluation of subsurface geologic data, collected as part of a ground-water investigation in northwestern Indiana, has led to a tentative differentiation of the glacial drift underlying Lake County, Ind. (fig. 157.1) into four distinctive lithologic units. These units are economically significant to the county as they serve as important sources of water supply. The lithologic units range in age from early Pleistocene to Recent and locally form a stratigraphic sequence more than 250 feet thick. They extend eastward and westward into adjacent counties in Indiana and Illinois. The subsurface geology of the units provides additional facts that may lead to a more comprehensive interpretation of the glacial history of the county. This history to date is based chiefly on interpretation of surface expression of deposits as described by Leverett and Taylor (1915), Wayne (1956, 1958), Zumberge (1960), and R. J. Vig (written communication, 1959).

The distribution and relationship of each unit are shown in the generalized sections on figure 157.2. The location of these sections is shown in figure 157.1. The oldest lithologic unit, tentatively designated unit 4, underlies about 500 square miles of the county and consists chiefly of till that is a gray to bluish-gray pebbly, sandy, silty clay, locally hard and compact. It ranges in thickness from 0 to more than 150 feet and in age from early Pleistocene to Illinoian. The till represents drift deposited during at least the Kansan and Illinoian Glaciations. The unit contains sev-

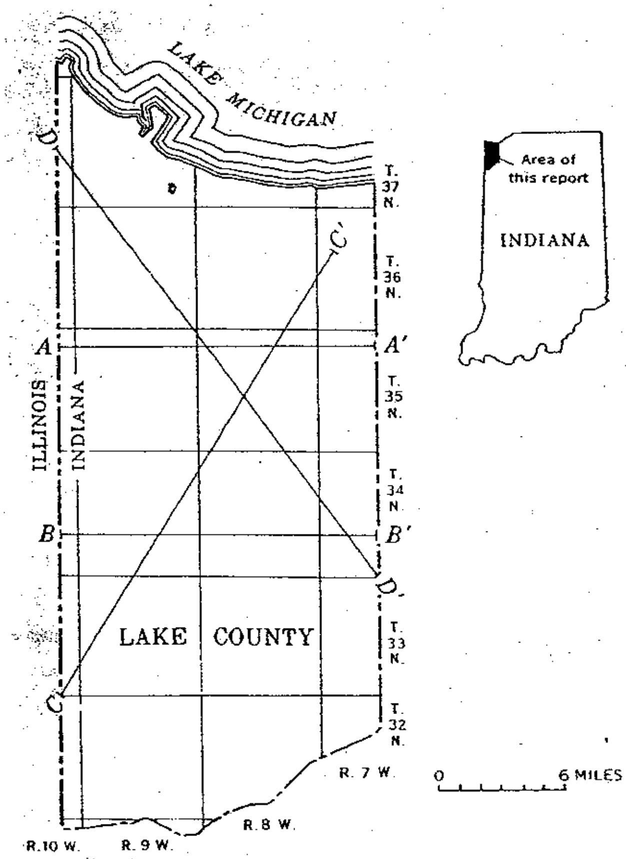

FIGURE 157.1.—Index map showing lines of sections (fig. 157.2), Lake County.

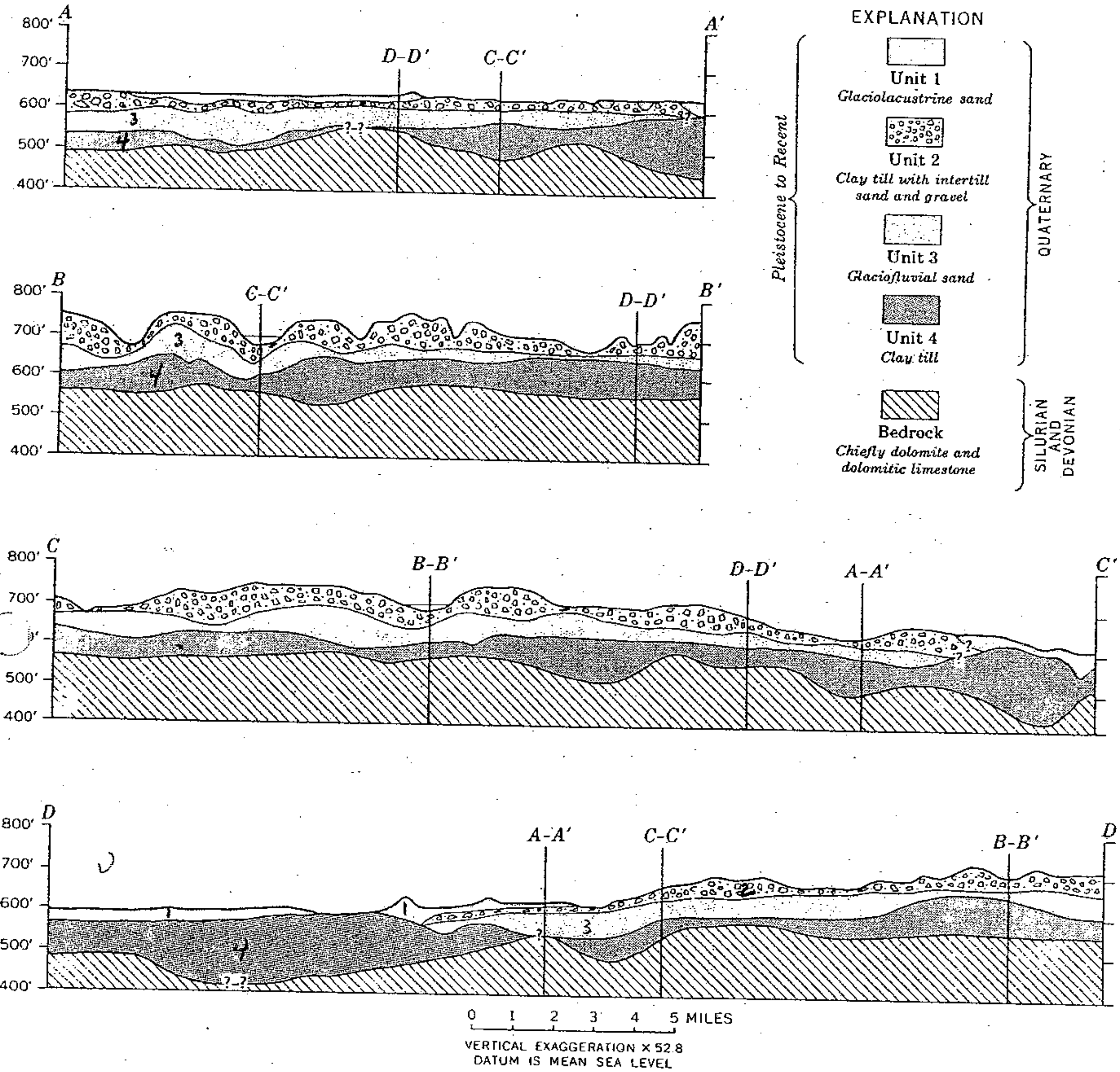

FIGURE 157.2.—Generalized sections showing lithologic units in glacial drift of Lake County.

eral relatively thin discontinuous sand or gravel zones that may represent intervals between these glaciations. The till mantles the bedrock almost everywhere in the county, except locally where the unit has been removed by postdepositional erosion, and it rests disconformably upon rocks of Silurian, Devonian, and Mississippian(?) ages. Locally in the northern part of the county the basal part of the unit consists of relatively thin sand or gravel. This sand or gravel partly fills the deeper parts of several preglacial valleys whose streams flowed northeastward toward the area underlying Lake Michigan.

Unit 4 is overlain disconformably in the southern two-thirds of the county by an extensive glaciofluvial deposit, tentatively designated unit 3, that is primarily of Illinoian age. Unit 3 consists chiefly of sand with some interbeds of sand and gravel, and very locally of thick clay. The unit ranges in thickness from 0 to 100 feet and underlies about 370 square miles of the county. It is thickest along its northern edge (fig.

157.2, sections $A-A'$ and $D-D'$) and in the western part of the county (fig. 157.2, sections $A-A'$ through $D-D'$) where locally it thickens toward Illinois (fig. 157.2, section $B-B'$). Postdepositional erosion has removed part of the unit in the western half of the county. The erosion accounts for the marked thickening and thinning of the unit here in relatively short lateral distances. This erosion took place during Sangamon time when several interglacial streams, which flowed northward and westward into Illinois, cut deeply into the unit.

The former stream system has somewhat influenced the topography of the present land surface. Several lakes occupy elongate depressions that coincide with these Sangamon interglacial valleys.

In the broad sandy plain in the southern quarter of the county, unit 3 grades upward into glaciofluvial and associated windblown sand that ranges in age from late Wisconsin to Recent. This younger sand, generally less than 10 feet thick, forms the upper part of unit 3. It is somewhat silty and clayey and is locally interbedded with layers of organically rich silt and clay of relatively small areal extent.

Unit 3 is overlain by a mantle of till that extends to the surface and forms the terminal and ground moraines of the Valparaiso morainic system. This surface expression is somewhat influenced by the topography of the underlying deposits of pre-Wisconsin age. The till, tentatively designated as unit 2, ranges in thickness from 0 to about 100 feet and in age from early to late Wisconsin. The unit underlies about 300 square miles in the central three-quarters of the county. It consists of a lower till member of early(?) Wisconsin age, a relatively thin intertill sand and gravel member, and an upper till member of late Wisconsin age. This sequence in part has been recognized by R. J. Vig (written communication, 1959). The lower till member is gray to bluish-gray pebbly, sandy clay that is locally hard. It ranges in thickness from 0 to about 80 feet, and contains discontinuous lenses of sand and gravel of small areal extent. The lower till member is overlain by a relatively thin sand and gravel member that is not present throughout the county but where present separates the upper till member from the lower till member. The upper till member is buff, yellow, or brown somewhat sandy, silty clay that ranges in thickness from 0 to about 60 feet and is late Wisconsin in age. This till is exposed at the surface in many parts of the county and comprises the surface material of the Valparaiso morainic system.

Unit 2 is overlain along its northern edge by glaciolacustrine sand, silt, and clay, that is herein tentatively designated unit 1. Unit 1 consists chiefly of fine to medium sand that is interbedded with zones of beach gravel, silt, and clay, all of which are locally organically rich. Along the eastern edge of the county the unit consists of alternating layers of thinly laminated silt and clay as much as 30 feet thick. Unit 1 was deposited on units 2 and 4 upon a surface that sloped gently, about 10 feet per mile, toward Lake Michigan.

Unit 1 ranges in thickness from 0 to about 70 feet. It underlies about 140 square miles of the county. The deposit is of late Wisconsin to Recent age and marks the transition period in the glacial history of Lake County between the formation of glacial Lake Chicago and the formation of Lake Michigan.

REFERENCES

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Zumberge, J. H., 1960, Correlation of Wisconsin drifts in Illinois, Indiana, Michigan, and Ohio: Geol. Soc. America Bull., v. 71, no. 8, p. 1,177–1,188.

STATE OF INDIANA

DEPARTMENT OF NATURAL RESOURCES

John E. Mitchell, Director

BULLETIN NO. 31

OF THE

DIVISION OF WATER

GEOHYDROLOGY AND GROUND-WATER POTENTIAL

OF LAKE COUNTY, INDIANA

BY

J. S. ROSENSHEIN AND J. D. HUNN

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preglacial weathering and erosion is also reported by Watkins and Rosenshein (1963) and Watkins and Ward (1962) in other parts of Indiana. This relationship was used in part to delineate the areas of transmissibility shown on plate 1.

The coefficient of storage (definition, p. 33) for the Silurian aquifer is estimated to average 0.0008. This estimate should be sufficiently accurate for evaluating regional characteristics of the dolomite in the county.

Recharge and Discharge

Fluctuations of the water level in the aquifer owing to seasonal variations in recharge and discharge are shown on figure 4. Recharge to the Silurian aquifer is derived from precipitation. The configuration of the piezometric surface (fig. 5) shows that this recharge occurs locally within the county. Ground water flows north and south from the aquifer's principal divide to points of discharge within the county and locally west and east to points of discharge outside the county. Down gradient from this divide recharge is added, chiefly by percolation through the overlying clayey till (unit 4, p. 21). Rosenshein (1963) has estimated that under present hydrologic conditions this recharge averages about 20,000 gpd per square mile.

Natural discharge takes place by upward movement of water from the Silurian where its head exceeds the head in the overlying rocks and by downward movement into the older rocks. Direct discharge by evapotranspiration can occur only in the extreme southwestern part of the county.

The estimated discharge of wells tapping the aquifer is 1.4 mgd or about 18 percent of the ground water pumped in the county. Of this amount 0.7 mgd is pumped for domestic and farm use, 0.6 mgd for municipal use, and 0.1 mgd for industrial and commercial use. Of the amount pumped by communities for municipal use, Dyer pumps 0.16 mgd, Lowell 0.21 mgd, St. John 0.02 mgd, Schererville 0.17 mgd, and Schneider 0.02 mgd.

Quality of Water

Water in the Silurian aquifer is generally hard although not as hard as that in the overlying drift. The dissolved ions consist chiefly of sodium, calcium, magnesium, and bicarbonate. Concentrations of the dissolved constituents and their significance are summarized in tables 2 and 3.

Geohydrologic control:--Recharge to the aquifer percolates through as much as 250 feet of unconsolidated rock. The water has lost much of its ability to dissolve dolomite by the time it reaches the Silurian. As a result, the properties of the water in the Silurian are not greatly influenced by the chemical composition of the rock composing the aquifer. Therefore, the water's chemical characteristics are determined to a large extent by the chemical characteristics of recharge derived from unit 4. As shown by table 2 all of the determined constituents except sodium and a small amount of chloride, are present in equal or greater amount in the water of the overlying principal Pleistocene aquifer, unit 3. Slightly higher concentration of chloride in water from the Silurian has no apparent significance.

the area approximately to the north and 50 feet in the area approximately to the south of the aquifer's principal divide (fig. 5). The yield for a specified drawdown will be greater for a larger diameter well than for a smaller diameter well. This relation also applies to longer or shorter pumping times. Because of these and other limitations, such as well efficiency, the map gives only an approximation of the capability of the aquifer as a source of water.

The Silurian aquifer will generally yield less than 200 gpm to properly constructed wells. Yields can possibly be increased by acidizing. Because the dolomite is argillaceous, some mud results from drilling. This mud should be removed to obtain the maximum yield. Removal may be aided by the use of polyphosphates.

The pumping level in a well should not be lowered below the top of the aquifer where the more permeable zones occur. Intermittent or continuous lowering of the water level below these zones can result in excessive precipitation of the dissolved solids from the water. The precipitation in the immediate vicinity of the well can cause a large decrease in well yield.

The depth to the top of the aquifer can be estimated from plate 2 for the western, northeastern, and southeastern parts of the county, where the Silurian forms the bedrock surface. This depth can be used in conjunction with plate 1 to estimate the depth to which a well must be drilled in order to develop a water supply. The thickness of the aquifer to be penetrated depends on the desired yield. The full thickness should be penetrated in areas of low transmissibility to obtain the largest yield. In areas of high transmissibility only the upper 25 feet or less need be penetrated for a domestic or farm supply.

The quantity of water potentially available for development from the Silurian is dependent upon its rate of recharge. This rate is controlled to a large extent by the geohydrologic properties of its confining layer. Recharge to the aquifer is currently estimated to be about 6 mgd. Rosenshein (1963) has shown that the rate of recharge will increase as the aquifer is extensively developed and estimates that its potential yield is about 24 mgd. The present pumpage is about 5 percent of this potential yield.

Devonian System

Middle Devonian Series

The dolomitic limestone and dolomite of Middle Devonian is not used extensively as a source of water. The estimated pumpage from this rock is about 10,000 gpd. Detailed information is lacking about its physical properties and its water-bearing characteristics. However, the information in the table below indicates that the limestone and dolomite is a potential source of only small quantities of water.

Unit 4

Water-bearing characteristics:--Unit 4 consists mainly of clay till that forms the principal confining layer overlying the dolomite of Silurian age. Recharge to the underlying rock occurs by downward movement of water through the till. The quantity of water passing through the unit depends in part on its vertical permeability. This permeability is estimated to average 0.003 gpd per square foot (Rosenshein, 1963).

The storage capacity is dependent upon porosity. The original porosity of the clay may have been as much as 50 to 60 percent. This porosity has been reduced by compaction since deposition and may now be 30 to 40 percent. Based on this porosity the unit may have as much as 6 million acre-feet of water in storage.

Development and potential:--The permeability of the clay is small, and it does not yield water readily to wells. Production from the unit is limited to discontinuous zones of intertill sand and gravel. These zones are used locally for domestic and farm supplies. Pumpage from the sand and gravel is estimated to be 100,000 gpd.

The basal part of the unit contains a relatively thin sand and gravel zone that fills the deeper parts of several preglacial valleys (fig. 7). The basal sand and gravel is generally less than 15 feet thick. It is a potential source of water for small supplies and has not been tapped to date.

Unit 3

Water-bearing characteristics

Unit 3 consists chiefly of sand (table 1) and forms the principal Pleistocene aquifer in the county. The aquifer is composed of an artesian and a water-table part. Its permeability ranges from less than 200 to more than 1,000 gpd per square foot and is estimated to average 600 gpd per square foot. The transmissibility ranges from less than 10,000 to more than 50,000 gpd per foot. The regional value is estimated to be 24,000 gpd per foot for the artesian part and 15,000 gpd per foot for the water-table part.

The coefficient of storage for the artesian part is estimated to average 0.003. In the southern part of the county, where the unit is water table, the coefficient of storage is estimated to average 0.12. These estimates should be sufficiently accurate to evaluate regional characteristics of the aquifer.

Recharge and discharge

Fluctuations of the water level in the aquifer owing to seasonal variations of recharge and discharge are shown on figure 8. Recharge to the unit is derived from local precipitation as shown by the configuration of the aquifer's piezometric surface (fig. 9).

The dissolved constituents in the water from the Silurian consist mainly of bicarbonate, calcium, magnesium, and sodium. Concentration of dissolved solids averages about 560 ppm. The constituents are derived chiefly from the recharge percolating through unit 4.

Unit 4, a clay till, is the confining layer overlying the bedrock. Its vertical permeability is estimated to average 0.003 gpd per square foot. The unit may have as much as 6 million acre-feet of water in storage. The clay contains some discontinuous zones of intertill sand and gravel from which about 100,000 gpd is pumped. Its basal part contains a thin sand and gravel zone that is not used but is a potential source of water for small supplies.

Unit 3, a sand, forms the principal Pleistocene aquifer. Its coefficient of transmissibility ranges from less than 10,000 to more than 50,000 gpd per foot. The estimated regional value of transmissibility for the artesian part is 24,000 gpd per foot and for the water-table part 15,000 gpd per foot. The estimated regional value of the coefficient of storage for the artesian part is 0.003 and that for the water-table part 0.12. Recharge to the artesian part is about 30 mgd under present hydrologic conditions. However, the estimated potential yield is 60 mgd. Direct recharge to the water-table part is about 1.2 mgd per square mile, and the estimated potential yield is 100 mgd. Development of this potential will require types of wells different from those commonly used in the area.

The principal dissolved constituents in the water from Unit 3 are calcium, magnesium, and bicarbonate. The concentration of dissolved solids averages about 550 ppm. The constituents in the artesian part are derived mostly from the recharge percolating through unit 2 and their concentrations in the aquifer are controlled to a large extent by the thickness of the confining layer.

Unit 2, a clay till, is the confining layer for the principal Pleistocene aquifer. Its vertical permeability is estimated to average 0.007 gpd per square foot. The unit may have as much as 3 million acre-feet of water in storage. Production from the unit is limited to intertill sand and gravel zones and is estimated to be 100,000 gpd. It is the most extensive unit exposed at the surface, and its hydrology is significant to both the ground- and surface-water resources of the county. This hydrology has been altered since the 1900's as a result of agricultural development and increase in rural nonfarm population. Under present hydrologic conditions the ground-water discharge from the unit to streams and ditches is about 110 mgd during the nongrowing season.

Unit 1, a sand, is chiefly a water-table aquifer. Its coefficient of transmissibility ranges from less than 5,000 to about 30,000 gpd per foot. The estimated regional value of transmissibility is 15,000 gpd per foot and that of the coefficient of storage 0.12. The hydrology of the unit has been markedly altered by industrial and urban development. Under present hydrologic conditions recharge is probably less than 600,000 gpd per square mile and the potential yield about 30 to 40 mgd. Development of this potential will require types of well different from those commonly used in the area and may be impeded by the unit's susceptibility to contamination by industrial and septic wastes.

Compendium of Rock-Unit Stratigraphy in Indiana

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STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY

prings Formation.") In subsurface usage, the a thinner, basically limestone unit. Known in . northern Crawford County to the southern ıe unit overlies the Tar Springs Formation lain with apparent conformity by the Walters- sconformably by the Mansfield Formation

The first Indiana reference to the term Vienna ook by Malott and Esarey (1940). When names pper Chesterian rocks in the state (Malott and Mississippian rocks above the Tar Springs ed to the Buffalo Wallow Formation, which Siberia Limestone at its base. In all probability, nestone is the Vienna, for a few years later eria was properly assigned to a higher position o be a member of the Menard Formation.

:r, Patoka Formation, CEW

:o Limestone Member was named as a part of on by Waddell (1954) for exposures along) in Vigo County (W½NW¼ sec. 28, T. 10 N., eparation), in redefining the Shelburn Forma- imestone Member in the Patoka Formation.

is a light- to dark-gray fossiliferous limestone black carbonaceous limestone. It is thickest '. 9 N., R. 10 W., in southern Vigo County and oughout much of its outcrop area in Sullivan outcrop and in the subsurface from northern d to the Ohio River.

agaran Series, Silurian System RHS

:e sections: The Wabash Formation was named (1964, p. 34-47) for all Niagaran rocks lying

above the Louisville Limestone, exclusive of rocks of the Salina Formation (which commonly is assigned to the Cayugan Series), in the upper Wabash Valley, Carroll, Cass, Miami, Wabash, and Huntington Counties, northern Indiana. Five principal reference sections were designated; the most complete is the rocks cored in the Northern Indiana Public Service Co. Gale M. and Glada Skinner No. 1 well near Royal Center, Cass County (NW¼NW¼ sec. 10, T. 28 N., R. 1 W), and others consist of some of the classic exposures of the reef section of northern Indiana.

Description: The Wabash Formation consists of rocks of three principal types that intergrade and replace one another spatially: (1) dolomitic siltstone to silty dolomite that is gray, dense to fine grained, argillaceous, and thick bedded to massive and that is characteristic of, but not confined to, the Mississinewa Shale Member in the lower part of the formation; (2) limestone and dolomitic limestone that is light colored, granular, fossil fragmental, cherty, and slabby bedded in weathered exposures and that is characteristic of, but not confined to, the Liston Creek Limestone Member in the upper part of the formation in and near its type area; and (3) light-colored granular vuggy massive nearly pure dolomite that is present as biohermal, bank, reef, and reef-detrital facies throughout the formation and that Pinsak and Shaver (1964, p. 39-40) referred to the Huntington Lithofacies as a replacement for the term Huntington Dolomite (Limestone, Stone) of older reports. The middle and upper parts of the formation are unassigned to member in western and northwestern Indiana, where regionally homogeneous divisions are lacking or poorly understood.

The formation is nearly 300 feet thick in west-central Indiana and as thick as 250 feet in places along its northern sinuous limit, between Fort Wayne and Lake Michigan, where it apparently terminates in a bank facies (Fort Wayne Bank) against the Salina Formation in not clearly understood relationship. Thicknesses are as much as 100 feet less in places southward where the overlying Salina Formation is near its southern limit and is complementary in thickness. Devonian rocks progressively overlap older parts of the eroded edge of the

USDA United States Department of Agriculture

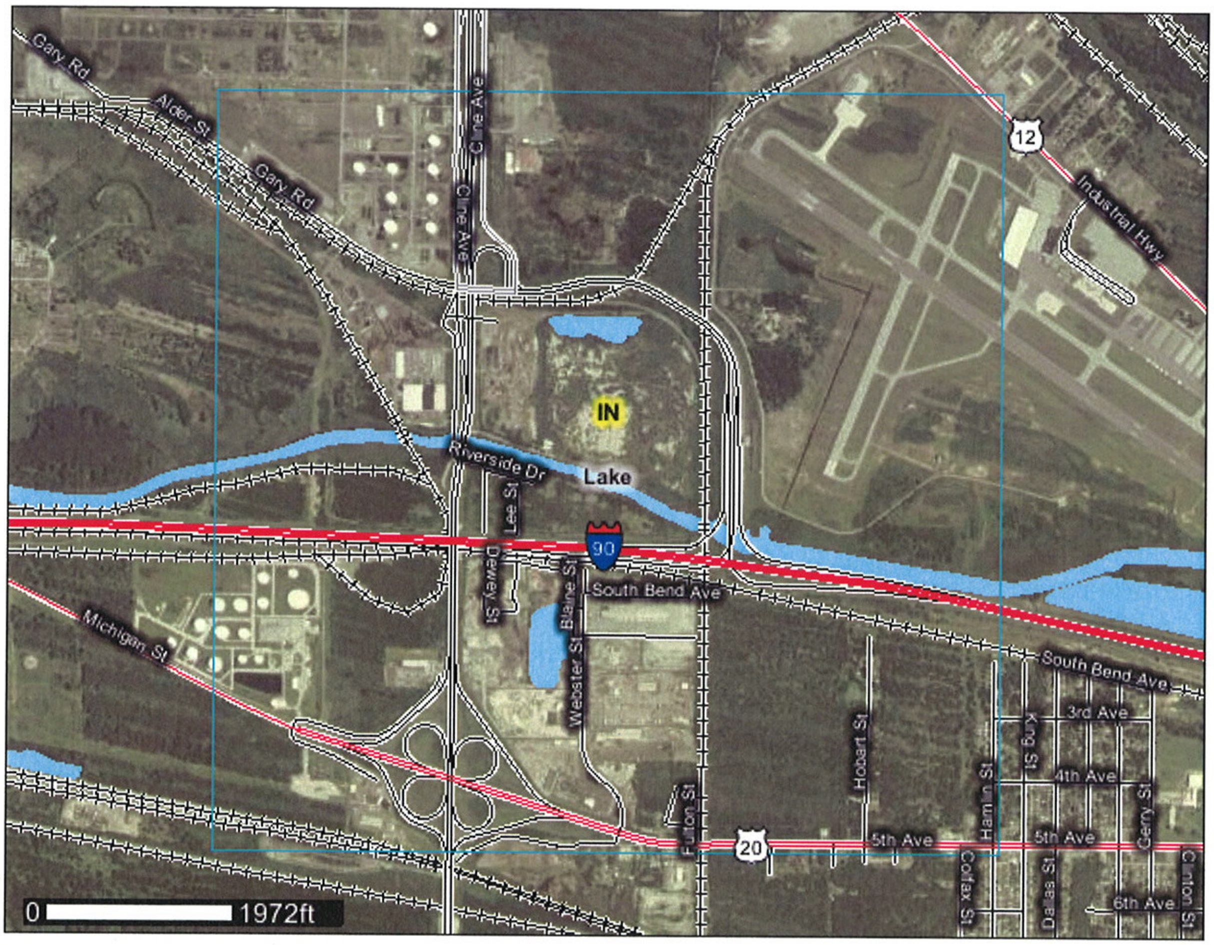
NRCS Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Lake County, Indiana

Gary Development Landfill, Lake County, IN



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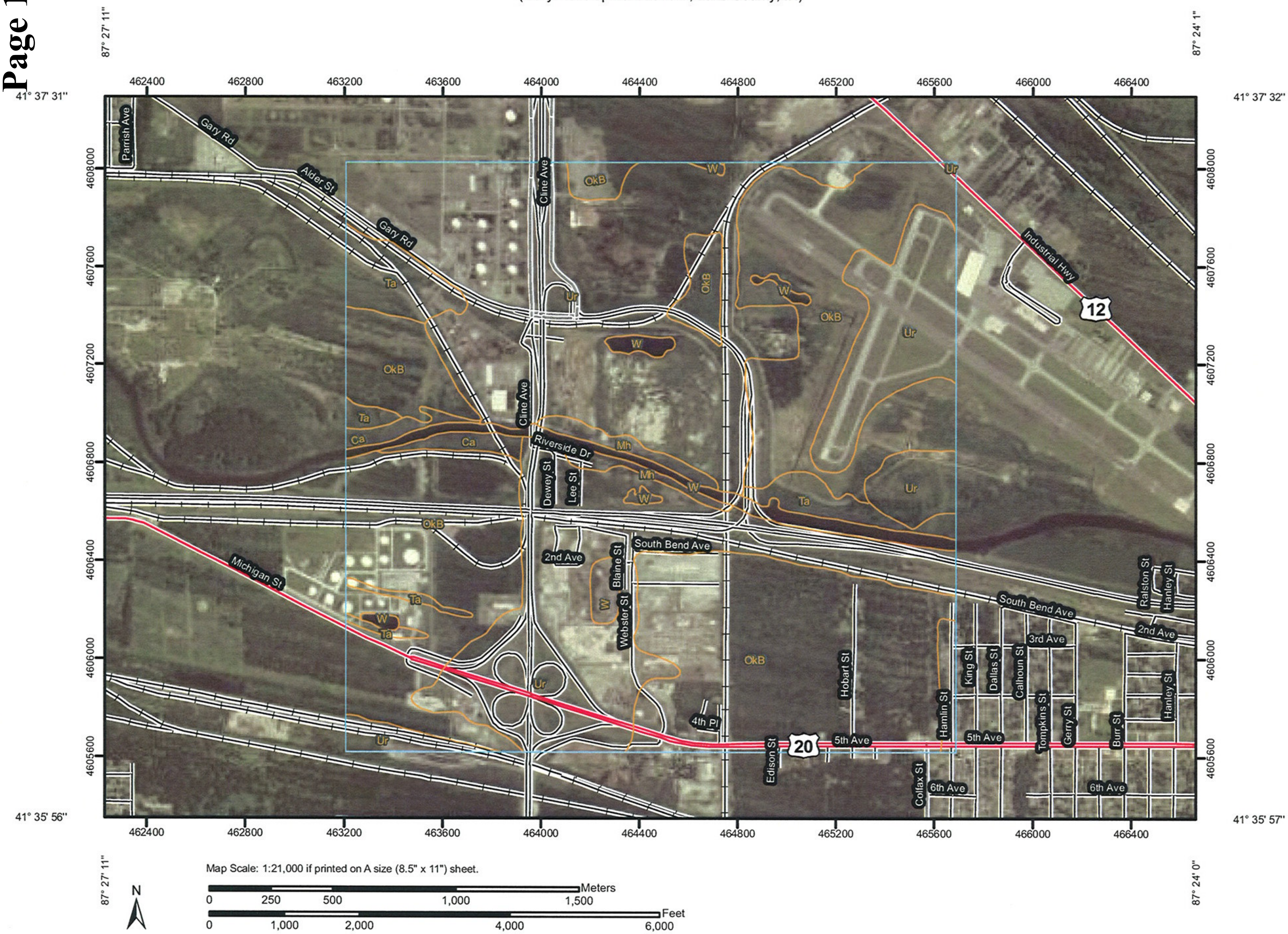
Soil Map—Lake County, Indiana
(Gary Development Landfill, Lake County, IN)



USDA Natural Resources Conservation Service

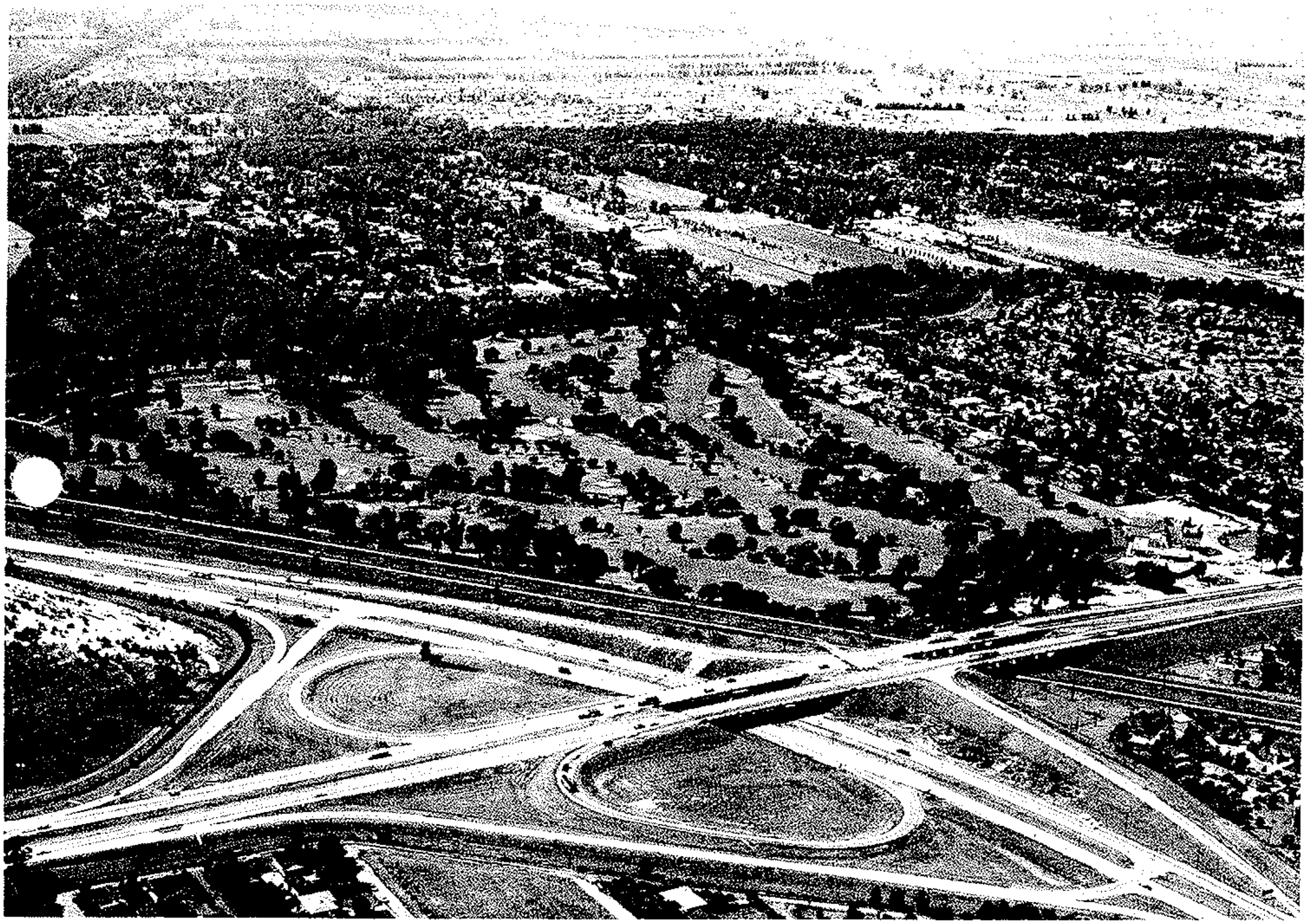
Web Soil Survey
National Coo[r]...tive Soil Survey

Map Unit Legend

Lake County, Indiana (IN089)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ca	Houghton muck, drained, 0 to 1 percent slopes	15.7	1.1%
Mh	Marsh	17.9	1.2%
OkB	Oakville-Adrian complex, 0 to 6 percent slopes	625.8	42.4%
Ta	Adrian muck, drained, 0 to 1 percent slopes	59.0	4.0%
Ur	Urban land	711.4	48.2%
W	Water	45.1	3.1%
Totals for Area of Interest		**1,474.9**	**100.0%**

SOIL SURVEY OF

Lake County, Indiana



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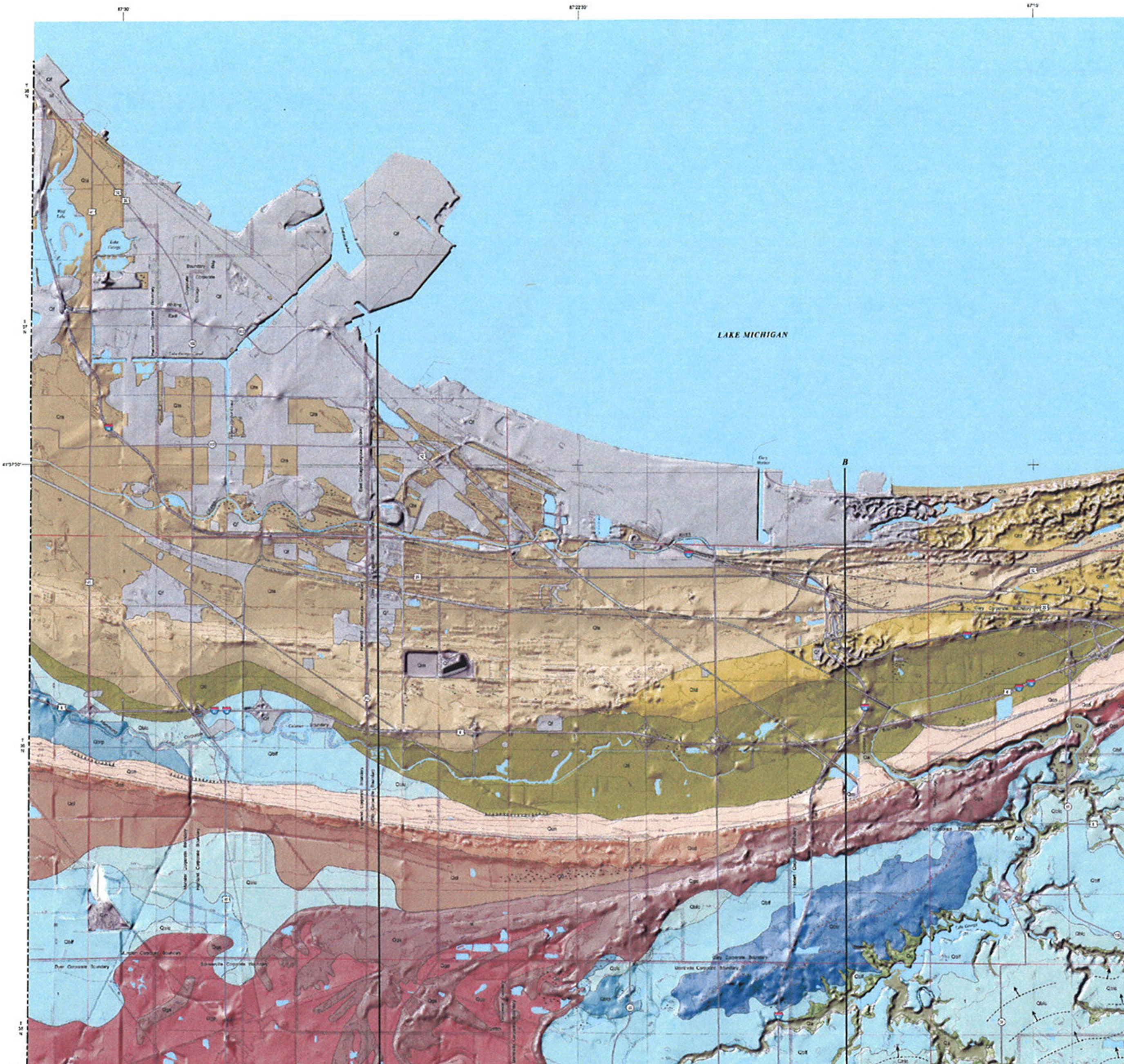
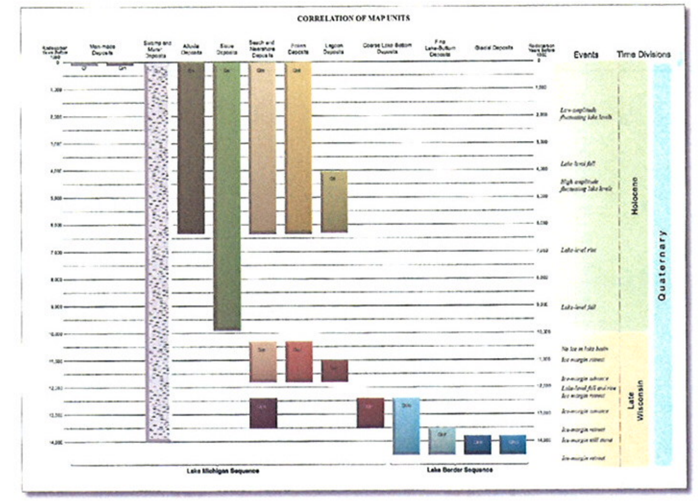
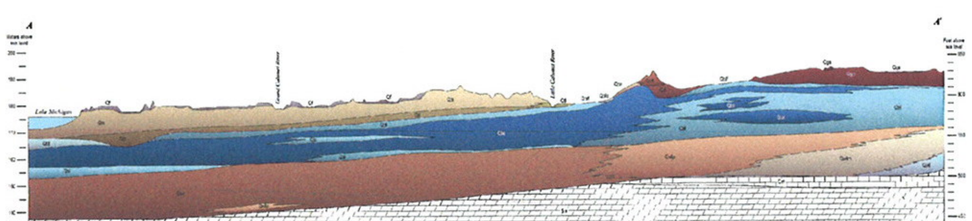
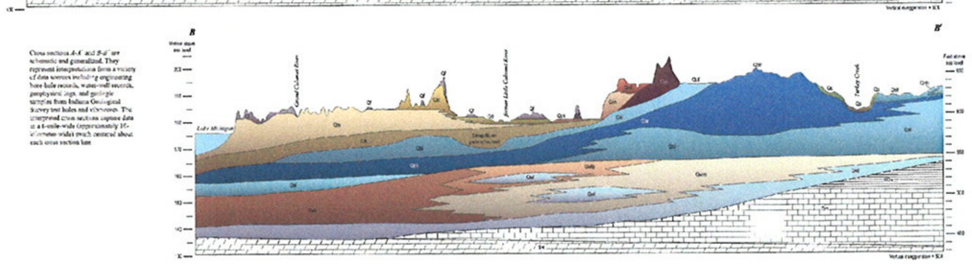


Base map features digitized from United States Geological Survey topographic quadrangle maps, scale 1:24,000
Projection: Universal Transverse Mercator (UTM) Zone 16 North.
Horizontal Datum: North American Datum of 1983 (NAD83)







DESCRIPTION OF MAP AND CROSS-SECTION UNITS

Map units define geologic terrains that include aspects of landscape and underlying depositional sequences. Map-unit boundaries are based primarily on geomorphology and secondarily on lithology. Vertical sequences within a geologic terrain are considered parts of a whole depositional system and may be composed of materials having a range of physical characteristics such as grain size or texture, internal organization, and geometries. In this context, sequences and landforms that compose a particular geologic terrain and that were deposited in a similar depositional environment exhibit certain lateral and vertical relationships to one another.

Map-unit definitions are both descriptive and interpretive. Descriptions include the type of geologic materials (for example, clay, silt, or sand); their range in thickness and relative positions within the sequence; total thickness of the sequence; lateral relations to other sequences and individual units; and overall variability of strata thicknesses, continuity, and texture. These definitions summarize the information provided by subsurface data such as water-well records; grain-size analyses, descriptions, and interpretations of down-hole drill and vibracore samples; natural gamma-ray logs; engineering borings, and field observations.

Interpretations focus on geologic events and processes that produced the vertical sequences and, where appropriate, associated landscape elements. Interpretations relate landform morphology of surface units and vertical and lateral facies relationships to glacial and postglacial geologic processes.

The map-unit descriptions also apply to the geologic cross sections. The cross sections include additional geologic units that are only in the subsurface and, therefore, are not shown on the map or ...

LAKE MICHIGAN SEQUENCE

LAKE BORDER SEQUENCE

Lake plain (fine facies)

The fine facies is dominantly stratified silt and clay and lesser amounts of interbedded sand deposited distal to the Lake Michigan Lobe margin. It forms a plain that exhibits very little relief and ranges from 590 to 640 feet (approximately 180 to 195 meters) in elevation.

Lake plain (coarse facies)

The coarse facies is dominantly bedded sand and fine gravel and lesser amounts of stratified silt and clay and loam to silt loam poorly sorted debris-flow sediment. It forms a plain that exhibits very little relief and ranges from 590 to 640 feet (approximately 180 to 195 meters) in elevation.

Sand and gravel of this unit range from 10 to 40 feet (approximately 3 to 12 meters) thick, and the debris-flow sediment is less than 10 feet (approximately 3 meters) thick.

In the western part of the map area, the source of the sand was the prograding Glenwood Beach. In the southeastern part of the map area, the coarse ...

WHEELER SEQUENCE

PALEOZOIC ROCK

INTRODUCTION

MAP AND CROSS-SECTION UNITS AND THEIR RELATIONSHIP TO THE REGIONAL GEOLOGIC SETTING

REFERENCES

Johnson, W. H., and Hansel, A. K., 1989, Age, stratigraphic position, and significance of the Lemont drift, northeastern Illinois: Journal of Geology, v. 97, p. 301–318.
Schneider, A. F., and Keller, S. J., 1970, Geologic map of the 1° x 2° Chicago Quadrangle, Indiana, Illinois and Michigan, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map 4, Part B, 1 sheet, scale 1:250,000

ADDITIONAL SOURCES OF INFORMATION

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program.

Digital cartography by Kimberly H. Sowder and Robin F. Rupp